2023–24 Bulletin

McKelvey School of Engineering Graduate Programs

Washington University in St. Louis

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About This Bulletin

The graduate and professional *Bulletins* are the catalogs of programs, degree requirements, courses that may be offered and course descriptions, pertinent university policies and faculty of the following schools of Washington University in St. Louis: Architecture & Urban Design; Art; Arts & Sciences; Business; Engineering; Law; Medicine; and Social Work & Public Health.

The *School of Continuing & Professional Studies Bulletin* is the catalog of the School of Continuing & Professional Studies, the professional and continuing education division at Washington University in St. Louis. The catalog includes programs, degree requirements, course descriptions and pertinent university policies for students earning a degree through the School of Continuing & Professional Studies.

The *2023-24 Bulletin* is entirely online but may be downloaded in PDF format for printing. Individual pages as well as information from individual tabs may be downloaded in PDF format using the PDF icon in the top right corner of each page. To download the full PDF, please choose from the following:

— The 2023-24 Bulletin PDFs will be available soon. —

- Architecture & Urban Design Bulletin (PDF)
- Art Bulletin (PDF)
- Arts & Sciences Bulletin (PDF)
- Business Bulletin (PDF)
- Engineering Bulletin (PDF)
- Law Bulletin (PDF)
- Medicine Bulletin (PDF)
- Social Work & Public Health Bulletin (PDF)
- School of Continuing & Professional Studies Bulletin (undergraduate & graduate) (PDF)

The degree requirements and policies listed in the *2023-24 Bulletin* apply to students entering Washington University during the 2023-24 academic year. For more information, please visit the Catalog Editions (p. 8) page.

Every effort is made to ensure that the information, applicable key policies and other materials presented in the *Bulletin* are accurate and correct as of the date of publication (July 5, 2023). To view a list of changes that have taken place after that date, visit the Program & Policy Updates page (http://bulletin.wustl.edu/about/updates/). Please note that the *Bulletin* highlights key university policies applicable to its students. Not all applicable university and departmental policies are included here.

Washington University reserves the right to make changes at any time without prior notice to the *Bulletin* and to university policies. Therefore, the electronic version of the *Bulletin* as published online is considered the official, governing document, and it may change from time to time without notice.

The next edition of the *Bulletin* will be published on July 1, 2024. In the interim, semester course offerings will be found in Washington University's Course Listings (https://courses.wustl.edu/Semester/Listing.aspx); these are usually available at the end of September for the upcoming spring semester, in early February for the upcoming summer semester, and in late February for the upcoming fall semester. Midyear changes to current courses (titles, descriptions, and credit units) are not reflected in this *Bulletin* and will only appear in the Course Listings. For more information about determining the appropriate edition of the *Bulletin* to consult, please visit the Catalog Editions page (p. 8) in the About This Bulletin section (http://bulletin.wustl.edu/about/).

For the most current information about registration and available courses, visit WebSTAC (https://acadinfo.wustl.edu) and Course Listings (https://courses.wustl.edu/Semester/Listing.aspx), respectively. Please email the Bulletin editor, Jennifer Gann, (jennifer.gann@wustl.edu) with any questions concerning the *Bulletin.*

Bulletin Policies

Changes to the Bulletin

Every effort is made to ensure that the information, policies and other materials presented in the *Bulletin* are accurate and correct as of the date of publication. For more information about the content review process for the Bulletin, please visit the Catalog Editions page (p. 8).

The *Bulletin* for the upcoming academic year is published annually on July 1, and certain post-publication changes may be made until October 1. To view a list of changes that have taken place after the July 1 publication date, please visit the Program & Policy Updates page (http://bulletin.wustl.edu/about/updates/).

Washington University reserves the right to make changes at any time without prior notice. Therefore, the electronic version of the *Bulletin* and the policies set forth therein may change from time to time without notice. The governing document at any given time is the then-current version of the *Bulletin,* as published online, and then-currently applicable policies and information are those contained in that *Bulletin.*

Discontinued Programs

Periodically, Washington University schools will change their program offerings. If a program is no longer accepting applicants, we will note this in the *Bulletin,* and soon after the program will be removed from the *Bulletin.* Students who are actively enrolled in these programs will be held to the requirements and policies published in the *Bulletin* from their year of matriculation. If a student has not been continuously enrolled in such a program and now wishes to inquire whether a discontinued program can still be completed, they should contact the relevant department or school to determine whether this opportunity is available.

Year of Matriculation

Students who attend Washington University are held to the policies in place as published in the *Bulletin* during their year of matriculation. For more information, please visit the Catalog Editions page (p. 8).

Course Numbering

Courses at Washington University are coded by department and include a three- or four-digit number that generally means the following, although students should check with the school or department offering the courses to be certain:

- 100 to 199 are primarily for first-year students;
- 200 to 299 are primarily for sophomores;
- 300 to 399 are primarily for juniors;
- 400 to 499 are primarily for juniors and seniors, although certain courses may carry graduate credit; and
- 500 and above are offered to graduate students and to juniors and seniors who have met all stated requirements. (If there are no stated requirements, juniors and seniors should obtain permission of the instructor.)

For example: Course L07 105 is an introductory course offered by the Department of Chemistry (L07).

The presence of a course in this *Bulletin* signifies that it is part of the curriculum currently offered and may be scheduled for registration. Enrollment requirements are determined by term.

Curriculum Designators

The designators shown below are used in Washington University's course descriptions and listed here alphabetically by code. The primary fields covered in each section are also listed.

A (Architecture)

Code	Name
A46 ARCH	Architecture
A48 LAND	Landscape Architecture
A49 MUD	Urban Design
AS1 MedSoc	Medicine and Society
AS2 PCS	Process Control Systems
AS3 UMSLEN	UMSL Joint Engineering Program

B (Business)

Code	Name
B50 ACCT	Accounting
B51 ADMN	Administration
B52 FIN	Finance
B53 MGT	Management
B54 MEC	Managerial Economics
B55 MKT	Marketing
B56 OB	Organizational Behavior
B57 SCOT	Supply Chain, Operations, and Technology
B59 DAT	Data Analytics
B60 ACCT	Graduate Accounting
B62 FIN	Graduate Finance
B63 MGT	Graduate Management
B64 MEC	Graduate Managerial Economics
B65 MKT	Graduate Marketing
B66 OB	Graduate Organizational Behavior
B67 SCOT	Graduate Supply Chain, Operations, and Technology
B69 DAT	Graduate Data Analytics
B90 BEE	Brookings Executive Education
B99 INTL	International Studies

E (Engineering)

Code	Name
E35 ESE	Electrical & Systems Engineering
E37 MEMS	Mechanical Engineering & Materials Science
E44 EECE	Energy, Environmental & Chemical Engineering
E60 Engr	General Engineering
E62 BME	Biomedical Engineering
E81 CSE	Computer Science & Engineering
EGS EGS	Engineering Graduate Studies

F (Art)

Code	Name
F00 Art	Art
F10 ART	Art (Core and Major Studio Courses)
F20 ART	Art (Elective Studio Courses)

I (Interdisciplinary Programs)

Code	Name
I02 MAIR	Military Aerospace Science
I25 MILS	Military Science
I50 INTER D	Interdisciplinary Studies
I52 IMSE	Institute of Materials Science & Engineering
I53 DCDS	Division of Computational and Data Sciences
I60 BEYOND	Beyond Boundaries

L (Arts & Sciences)

Code	Name
L01 Art-Arch	Art History and Archaeology
L04 Chinese	Chinese
L05 Japan	Japanese
L07 Chem	Chemistry
L08 Classics	Classics
L09 Greek	Greek
L10 Latin	Latin
L11 Econ	Economics
L12 Educ	Education
L13 Writing	Writing

L14 E Lit	English Literature
L15 Drama	Drama
L16 Comp Lit	Comparative Literature
L18 URST	Urban Studies
L19 EEPS	Earth, Environmental, and Planetary Sciences
L21 German	Germanic Languages and Literatures
L22 History	History
L23 Re St	Religious Studies
L24 Math	Mathematics and Statistics
L27 Music	Music
L28 P.E.	Physical Education
L29 Dance	Dance
L30 Phil	Philosophy
L31 Physics	Physics
L32 Pol Sci	Political Science
L33 Psych	Psychological & Brain Sciences
L34 French	French
L36 Ital	Italian
L37 Portug	Portuguese
L38 Span	Spanish
L39 Russ	Russian
L40 SOC	Sociology
L41 Biol	Biology and Biomedical Sciences
L43 GeSt	General Studies
L44 Ling	Linguistics
L45 LatAm	Latin American Studies
L46 AAS	Asian American Studies
L48 Anthro	Anthropology
L49 Arab	Arabic
L51 Korean	Korean
L52 ARC	Archaeology
L53 Film	Film and Media Studies
L56 CFH	Center for the Humanities
L57 RelPol	Center on Religion and Politics
L59 CWP	College Writing Program
L61 FYP	First-Year Programs
L62 Praxis	Praxis
L63 IPMS	Movement Science
L64 PNP	Philosophy-Neuroscience-Psychology
L66 ChSt	Children's Studies
L73 Hindi	Hindi
L74 HBRW	Hebrew
L75 JIMES	Jewish, Islamic, and Middle Eastern Studies
L77 WGSS	Women, Gender, and Sexuality Studies
L81 EALC	East Asian Languages & Cultures
L82 EnSt	Environmental Studies
L84 Lw St	Legal Studies
L85 MedH	Medical Humanities
L86 PBPM Study	Biological & Physical Sciences for PBPM
L89 Sphr	Speech and Hearing
L90 AFAS	African and African-American Studies
L92 APL	Applied Linguistics
L93 IPH	Interdisciplinary Project in the Humanities
L97 GS	Global Studies
L98 AMCS	American Culture Studies
L99 OSP	Overseas Programs
LGS GSAS	The Graduate School

M (Medicine)

Code	Name
M01 OT	Occupational Therapy Program
M02 PhysTher	Physical Therapy Program-Grad
M04 FYSelect	First-Year Selectives
M05 Neurosci	Neuroscience
M10 Anesth	Anesthesiology
M15 Biochem	Biochemistry and Molecular Biophysics
M17 CLNV	Clinical Investigation
M18 BMI	Biomedical Informatics
M19 PHS	Population Health Sciences
M20 Genetics	Genetics
M21 MSB	Biostatistics and Genetic Epidemiology
M25 Medicine	Internal Medicine
M26 FamMed	Family Medicine
M27 EMED	Emergency Medicine
M30 MolMB	Molecular Microbiology
M35 Neurol	Neurology
M40 NeurSurg	Neurological Surgery
M45 ObGyn	Obstetrics and Gynecology
M50 Ophth	Ophthalmology and Visual Sciences
M55 Oto	Otolaryngology
M60 Path	Pathology
M65 Peds	Pediatrics
M70 MolBio/Pha	Molecular Biology and Pharmacology
M75 CellBio	Cell Biology and Physiology
M80 Interdis	Interdisciplinary
M81 Gateway	Gateway Curriculum
M85 Psych	Psychiatry
M88 AHBR	Applied Health Behavior Research
M89 PACS	Audiology and Communication Sciences
M90 Radiol	Radiology

M91 MedPhys	Medical Physics
M92 RadOnc	Radiation Oncology
M93 NrsSci	Nursing Science
M95 Surgery	Surgery
M96 Ortho	Orthopedic Surgery
M99 Ind Stdy	Independent Study

S (Social Work and Public Health)

Code	Name
S15 SWCR	MSW Foundation
S20 SWHS	Theory, Problems & Issues
S30 SWDP	Practice Methods
S31 SWDP	Practice Methods
S40 SWSP	Social Policy
S48 SWSP	Social Policy
S50 SWSA	Practice Methods
S55 MPH	Master of Public Health (MPH)
S60 SWCD	Practice Methods
S65 SWCD	Practice Methods
S70 SWPR	MSW Practicum
S81 SKILL	Skill Labs
S90 SWDT	Brown PhD
S91 PSTM	Post-Master Certificate

T (Engineering - Joint Program & Sever Institute)

Code	Name
T11 JCS	Joint Introduction to Computing
T54 PRJM	Project Management
T55 ETEM	Engineering Management
T64 CNST	Construction Management
T71 HLTHCARE	Health Care Operations
T81 INFO	Information Management
T83 CYBER	Cybersecurity Management
T92 HCO	Health Care Operations (Online)
T93 CSM	Cybersecurity Management (Online)
T95 EMGT	Engineering Management (Online)

U (School of Continuing & Professional Studies)

Code	Name
U02 Classics	Classics
U03 GS	General Studies
U05 Chem	Chemistry
U07 Econ	Economics
U08 Educ	Education
U09 Psych	Psychological & Brain Sciences (Psychology)
U10 ArtArch	Art History and Archaeology
U11 EComp	English Composition
U12 Fr	French
U13 EPSc	Earth and Planetary Sciences
U14 German	Germanic Languages and Literatures
U15 ELP	English Language Programs
U16 Hist	History
U18 Film	Film and Media Studies
U19 SUST	Sustainability
U20 Math	Mathematics and Statistics
U21 Drama	Drama
U22 Phil	Philosophy
U23 Phys	Physics
U24 Mus	Music
U25 PolSci	Political Science
U26 Port	Portuguese
U27 Span	Spanish
U29 Bio	Biology
U30 Spch	Speech
U31 Dance	Dance and Somatic Movement Studies
U32 CompLit	Comparative Literature
U35 Arab	Arabic
U36 Japan	Japanese
U37 Hebr	Hebrew
U38 Chinese	Chinese
U39 Russ	Russian
U40 Ital	Italian
U43 IS	International Studies
U44 Bus	Business
U47 IRISH	Irish Studies
U48 Comm	Communications
U49 JRN	Journalism
U51 KOREAN	Korean
U56 ISLA	Integrated Studies in Liberal Arts
U65 ELit	English and American Literature
U66 RelSt	Religious Studies
U67 LAS	Latin American Studies

U68 SOC	Sociology
U69 Anthro	Anthropology
U71 DATA	Data Studies
U73 Hindi	Hindi
U74 Sci	Science
U76 NPM	Nonprofit Management
U78 EAsia	East Asian Studies
U79 Art	Art
U80 CRM	Clinical Research Management
U82 CIM	Computers and Information Management
U84 AFAS	African and African-American Studies
U85 IA	International Affairs
U86 HCARE	Health Care
U87 HRM	Human Resources Management
U89 AMCS	American Culture Studies
U90 GIS	Geographic Information Systems
U91 Ling	Linguistics
U92 WGSS	Women, Gender, and Sexuality Studies
U93 Scan	Scandinavian
U94 JME	Jewish, Islamic, and Middle Eastern Studies
U96 DLA	DLA Seminars
U98 MLA	MLA Seminars

W (Law)

Code	Name
W74 LAW	Law

X (Design & Visual Arts)

Code	Name
X10 XCORE	Design & Visual Arts - Core
X20 XELEC	Design & Visual Arts - Elective

Catalog Editions

The courses and policies listed in this *Bulletin* are subject to change at any time through normal approval channels within Washington University. New courses, changes to existing course work and new policies are initiated by the appropriate institutional departments, committees or administrators. Academic policy revisions are generally implemented in the next academic year following notification thereof. Washington University publishes a new edition of the *Bulletin* each July, and its contents apply to the subsequent fall, spring, and summer terms. Occasionally a policy or requirement must be changed and implemented during the same academic year (e.g., in the case of relevant external requirements such as state regulations). All changes must be approved by college or school personnel who oversee academic curriculum and policies.

Washington University students must complete the graduation requirements in effect during the term that they matriculated into their program of study as published in the edition of the *Bulletin* from that academic year. Undergraduates who initially enroll in a summer term to pursue a special program follow requirements for the subsequent fall term. Students will need to check their school's processes to potentially change applicable catalog years or alter their degree requirements.

Students should review specific Washington University and individual school policies related to transfer credit, changing programs, leaves of absence, and military service.

Prior Bulletins

To find program details, course descriptions, and relevant policies, choose the year of enrollment below to find the available *Bulletins.* If the required year is not shown or the school's *Bulletin* is not available, please email the Office of the University Registrar (registrar@wustl.edu) with specifics of the needed information.

2022-2023

The HTML versions of the 2022-23 Bulletins are coming soon.

- Graduate Architecture & Urban Design Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Grad_Arch.pdf))
- Graduate Art Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Grad_Art.pdf))
- Graduate Arts & Sciences Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Grad_Arts_Sciences.pdf))
- Graduate Business Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Grad_Business.pdf))
- Graduate Engineering Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Grad_Engineering.pdf))
- Law Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Law.pdf))
- Medicine Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Medicine.pdf))
- Social Work & Public Health Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Brown.pdf))
- Undergraduate Bulletin (HTML) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_Undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate, Graduate) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2022-23_UCollege.pdf))

2021-2022

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Grad_Arch.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Grad_Art.pdf))

- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Grad_School.pdf))
- Graduate Business Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/grad/business/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Grad_Business.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Grad_Engineering.pdf))
- Law Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/law/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Law.pdf))
- Medicine Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/medicine/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Medicine.pdf))
- Social Work & Public Health Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/brownschool/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Brown.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2021-22/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_Undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2021-22/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2021-22/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2021-22_UCollege.pdf))

2020-2021

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Grad_Arch.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Grad_Art.pdf))
- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Grad_School.pdf))
- Graduate Business Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/grad/business/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Grad_Business.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Grad_Engineering.pdf))
- Law Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/law/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Law.pdf))
- Medicine Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/medicine/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Medicine.pdf))
- Social Work & Public Health Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/brownschool/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Brown.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2020-21/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_Undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2020-21/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2020-21/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2020-21_UCollege.pdf))

2019-2020

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_grad_architecture.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_grad_art.pdf))
- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_graduate_school.pdf))
- Graduate Business Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/grad/business/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_grad_business.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_grad_engineering.pdf))
- Law Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/law/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_law.pdf))
- Medicine Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/medicine/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_medicine.pdf))
- Social Work & Public Health Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/brownschool/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_brownschool.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2019-20/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2019-20/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2019-20/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2019-20_university_college.pdf))

2018-2019

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_grad_architecture.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_grad_art.pdf))
- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_graduate_school.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_grad_engineering.pdf))
- Law Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/law/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_law.pdf))
- Medicine Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/medicine/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_medicine.pdf))
- Social Work & Public Health Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/brownschool/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_brownschool.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2018-19/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2018-19/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2018-19/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2018-19_university_college.pdf))

2017-2018

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_grad_architecture.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_grad_art.pdf))
- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_graduate_school.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_grad_engineering.pdf))
- Law Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/law/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_law.pdf))
- Medicine Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/medicine/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_medicine.pdf))
- Social Work & Public Health Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/brownschool/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_brownschool.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2017-18/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2017-18/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2017-18/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2017-18_university_college.pdf))

2016-2017

- Graduate Architecture & Urban Design Bulletin (HTML (https://bulletin.wustl.edu/prior/2016-17/grad/architecture/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_grad_architecture.pdf))
- Graduate Art Bulletin (HTML (https://bulletin.wustl.edu/prior/2016-17/grad/art/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_grad_art.pdf))
- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2016-17/grad/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_graduate_school.pdf))
- Graduate Engineering Bulletin (HTML (https://bulletin.wustl.edu/prior/2016-17/grad/engineering/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_grad_engineering.pdf))
- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/bulletin17.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2016-17/undergrad/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_undergraduate.pdf))
- University College Bulletin (HTML: Undergraduate (https://bulletin.wustl.edu/prior/2016-17/undergrad/ucollege/), Graduate (https://bulletin.wustl.edu/prior/2016-17/grad/ucollege/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2016-17_university_college.pdf))

2015-2016

- Graduate Arts & Sciences Bulletin (HTML (https://bulletin.wustl.edu/prior/2015-16/gsas/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2015-16_gsas.pdf))
- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2015-2016_Bulletin_FINAL_3-2-16_.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2015-16/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2015-16_undergraduate.pdf))

2014-2016

- University College Bulletin (undergraduate & graduate) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2014-2016_UCollege.pdf))

2014-2015

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2014-2015_bulletin.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2014-15/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2014-2015.pdf))

2013-2014

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2013-2014_bulletin.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2013-14/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_13-14.pdf))

2012-2015

- Graduate Arts & Sciences Bulletin (PDF (http://bulletin.wustl.edu/about/prior/GSAS_Bulletin_2012-2015.pdf))

2012-2014

- University College Bulletin (undergraduate & graduate) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin_2012-2014_UCollege.pdf))

2012-2013

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2012-2013_bulletin.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2012-13/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin 12-13.pdf))

2011-2012

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2011-2012_bulletin.pdf))
- Undergraduate Bulletin (HTML (https://bulletin.wustl.edu/prior/2011-12/)) (PDF (http://bulletin.wustl.edu/about/prior/Bulletin 11-12.pdf))

2010-2011

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2010-2011_bulletin.pdf))
- Undergraduate Bulletin (PDF (http://bulletin.wustl.edu/about/prior/Bulletin 10-11.pdf))

2009-2012

- Graduate Arts & Sciences Bulletin (PDF (http://bulletin.wustl.edu/about/prior/GSAS_Bulletin_2009-2012.pdf))

2009-2010

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2009-2010_bulletin.pdf))

2008-2010

- Undergraduate Bulletin (PDF (http://bulletin.wustl.edu/about/prior/Bulletin 08-10.pdf))

2008-2009

- Medicine Bulletin (PDF (http://bulletin.wustl.edu/about/prior/2008-2009_bulletin.pdf))

2006-2009

- Graduate Arts & Sciences Bulletin (PDF (http://bulletin.wustl.edu/about/prior/GSAS_Bulletin_2006-2009.pdf))
  and accompanying 2008 Update (PDF (http://bulletin.wustl.edu/about/prior/GSAS_Bulletin_2008_insert.pdf))

2006-2008

- Undergraduate Bulletin (PDF (http://bulletin.wustl.edu/about/prior/Bulletin 06-08.pdf))

About Washington University in St. Louis

Who We Are Today

Washington University in St. Louis — a medium-sized, independent university — is dedicated to challenging its faculty and students alike to seek new knowledge and greater understanding of an ever-changing, multicultural world. The university is counted among the world's leaders in teaching and research, and it draws students from all 50 states, the District of Columbia, Guam, Puerto Rico and the Virgin Islands. Students and faculty come from more than 100 countries around the world.

The university offers more than 250 programs and 5,500 courses leading to associate, bachelor's, master's, and doctoral degrees in a broad spectrum of traditional and interdisciplinary fields, with additional opportunities for minor concentrations and individualized programs. For more information about the university, please visit the University Facts (http://wustl.edu/about/facts/) page of our website.

Enrollment by School

For enrollment information (https://wustl.edu/about/university-facts/#students), please visit the University Facts page of our website.

Our Mission Statement

The mission of Washington University in St. Louis is to act in service of truth through the formation of leaders, the discovery of knowledge and the treatment of patients for the betterment of our region, our nation and our world.

At WashU, we generate, disseminate, and apply knowledge. We foster freedom of inquiry and expression of ideas in our research, teaching and learning.

We aim to create an environment that encourages and supports wide-ranging exploration at the frontier of discovery by embracing diverse perspectives from individuals of all identities and backgrounds. We promote higher education and rigorous research as a fundamental component of an open, vibrant society. We strive to enhance the lives and livelihoods not only of our students, patients, and employees but also of the people of the greater St. Louis community and beyond. We do so by addressing scientific, social, economic, medical, and other challenges in the local, national, and international realms.

Our goals are:

- to foster excellence and creativity in our teaching, research, scholarship, patient care and service
- to welcome students, faculty and staff from all backgrounds to create an inclusive, equitable community that is nurturing and intellectually rigorous
- to cultivate in students habits of lifelong learning and critical and ethical thinking, thereby enabling them to be productive members and leaders of a global society
- to contribute positively to our home community of St. Louis, and to effect meaningful, constructive change in our world

To this end we intend:

- to hold ourselves to the highest standards of excellence
- to educate aspiring leaders of great ability from diverse backgrounds
- to encourage faculty and students to be innovative, bold, independent, critical thinkers
- to build an inclusive, equitable, respectful, ethically-principled environment for living, teaching, learning and working for the present and future generations
- to focus on meaningful and measurable outcomes for all of our endeavors

Mission statement approved by the Faculty Senate Council in April 2021 and approved by the Board of Trustees on October 1, 2021.

Trustees & Administration

Board of Trustees

Washington University's Board of Trustees is the chief governing body of Washington University in St. Louis. Please visit the Board of Trustees website (http://boardoftrustees.wustl.edu) for more information.

University Administration

In 1871, Washington University co-founder and then-Chancellor William Greenleaf Eliot sought a gift from Hudson E. Bridge, a charter member of the university's Board of Directors, to endow the chancellorship. Soon after this endowment was received, the position was renamed the "Hudson E. Bridge Chancellorship."

The officers of the university administration are currently led by Chancellor Andrew D. Martin. University leadership (https://wustl.edu/about/leadership/) is detailed on the Washington University website.

Academic Calendar

The academic calendar of Washington University in St. Louis is designed to provide an optimal amount of classroom instruction and examination within a manageable time frame, facilitating our educational mission to promote learning among both students and faculty. Individual schools — particularly our graduate and professional schools — may have varying calendars due to the nature of particular fields of study. Please refer to each school's website for more information.

Fall Semester 2023

College of Arts & Sciences, McKelvey School of Engineering, Olin Business School, Sam Fox School of Design & Visual Arts, and the School of Continuing & Professional Studies

Date	Day	Description
August 28	Monday	First day of classes
September 4	Monday	Labor Day (no classes)
October 7-10	Saturday-Tuesday	Fall Break (no classes)
November 22-26	Wednesday-Sunday	Thanksgiving Break (no classes)
December 8	Friday	Last day of classes
December 11-20	Monday-Wednesday	Reading and finals

Spring Semester 2024

College of Arts & Sciences, McKelvey School of Engineering, Olin Business School, Sam Fox School of Design & Visual Arts, and the School of Continuing & Professional Studies

Date	Day	Description
January 16	Tuesday	First day of classes
March 10-16	Sunday-Saturday	Spring Break (no classes)
April 26	Friday	Last day of classes
April 29-May 8	Monday-Wednesday	Reading and finals

Commencement Ceremonies

Date	Day	Description
May 13	Monday	Class of 2024 Commencement

Summer Semester 2024

Date	Day	Description
May 20	Monday	First Summer Session begins
May 27	Monday	Memorial Day (no classes)
July 4	Thursday	Independence Day (no classes)
August 15	Thursday	Last Summer Session ends

Washington University recognizes the individual student's choice in observing religious holidays (https://bpb-us-w2.wpmucdn.com/sites.wustl.edu/dist/c/2883/files/2021/12/Religious-Holiday-Class-Absence-Policy-Final_November-2021.pdf). Students are encouraged to make arrangements with instructors to complete work missed due to religious observance. Instructors are asked to make every reasonable effort to accommodate such requests.

Campus Resources

Student Support Services

The Learning Center. The Learning Center is located on the lower level of the Mallinckrodt Center, and it is the hub of academic support at Washington University in St. Louis. We provide undergraduate students with assistance in a variety of forms. Most services are free, and each year more than 2,000 students participate in one or more of our programs. For more information, visit the Learning Center website (https://ctl.wustl.edu/learningcenter/) or call 314-935-5970. There are three types of services housed within the Learning Center:

- **Academic Mentoring Programs** offer academic support in partnership with the academic departments in a variety of forms. Academic mentoring programs are designed to support students in their course work by helping them develop the lifelong skill of "learning how to learn" and by stimulating their independent thinking. Programs include course-specific weekly structured study groups facilitated by highly trained peer leaders as well as course-specific weekly walk-in sessions facilitated by academic mentors in locations, at times and in formats convenient for the students. The Learning Center also offers individual consulting/coaching for academic skills such as time management, study skills, note taking, accessing resources and so on. Other services include fee-based graduate and professional school entrance preparation courses.
- **Disability Resources** supports students with disabilities by fostering and facilitating an equal access environment for the Washington University community of learners. Disability Resources partners with faculty and staff to facilitate academic and housing accommodations for students with disabilities on the Danforth Campus. Students enrolled in the School of Medicine should contact their program's director. Please visit the Disability Resources website (https://students.wustl.edu/disability-resources/) or contact the Learning Center at 314-935-5970 for more information.
- **TRIO: Student Support Services** is a federally funded program that provides customized services for undergraduate students who are low income, who are the first in their family to go to college, and/or who have a documented disability. Services include academic coaching, academic peer mentoring, cultural and leadership programs, summer internship assistance and post-graduation advising. First-year and transfer students are considered for selection during the summer before they enter their first semester. Eligible students are encouraged to apply when they are notified, because space in this program is limited. For more information, visit the TRIO Program website (https://students.wustl.edu/trio-program/).

Medical Student Support Services. For information about Medical Student Support Services, please visit the School of Medicine website (https://medicine.wustl.edu).

Office for International Students and Scholars. If a student is joining the university from a country other than the United States, this office can assist that individual through their orientation programs, issue certificates of eligibility (visa documents), and provide visa and immigration information. In addition, the office provides personal and cross-cultural counseling and arranges social, cultural and recreational activities that foster international understanding on campus.

The Office for International Students and Scholars is located on the Danforth Campus in the Danforth University Center at 6475 Forsyth Boulevard, Room 330. The office can be found on the Medical Campus in the Mid Campus Center (MCC Building) at 4590 Children's Place, Room 2043. For more information, visit the Office for International Students and Scholars website (https://students.wustl.edu/international-students-scholars/) or call 314-935-5910.

Office of Military and Veteran Services. This office serves as the university's focal point for military and veteran matters, including transitioning military-connected students into higher education, providing and connecting students with programs and services, and partnering across campus and in the community. Services include advising current and prospective students on how to navigate the university and maximize Department of Defense and Veterans Affairs (VA) educational benefits, transition support, Veteran Ally training for faculty and staff, veteran-unique programming, and connecting students to campus and community resources. Military-connected students include veterans, military service members, spouses, dependent children, caregivers, survivors and Reserve Officer Training Corp cadets. There are two university policies that apply to students who still serve in the Armed Forces and students who use VA educational benefits:

- The Policy on Military Absences, Refunds and Readmissions (https://veterans.wustl.edu/policies/policy-for-military-students/) applies to students serving in the U.S. Armed Forces and their family members when military service forces them to be absent or withdraw from a course of study.
- The Policy on Protections for VA Educational Benefit Users (https://veterans.wustl.edu/policies/policy-for-va-students/) applies to students using VA education benefits when payments to the institution and the individual are delayed through no fault of the student.

The Office of Military and Veteran Services is located in Umrath Hall on the Danforth Campus. Please visit the Military and Veteran Services website (https://veterans.wustl.edu/) or send an email to veterans@wustl.edu for more information.

Relationship and Sexual Violence Prevention (RSVP) Center. The RSVP Center offers free and confidential services including 24/7 crisis intervention, counseling services, resources, support and prevention education for all students on the Danforth Campus. The RSVP Center operates from a public health model and uses trauma-informed practices to address the prevalent issues of relationship and sexual violence. By providing support for affected students, it is our goal to foster post-traumatic growth and resilience and to help ensure academic retention and success. Our prevention efforts call for community engagement to engender an intolerance of violence and an active stance toward challenging cultural injustices that perpetuate such issues. Learn more at the RSVP Center website (https://students.wustl.edu/relationship-sexual-violence-prevention-center/).

WashU Cares. WashU Cares assists the university with handling situations involving the safety and well-being of Danforth Campus students. WashU Cares is committed to fostering student success and campus safety through a proactive, collaborative and systematic approach to the identification of, intervention with and support of students of concern while empowering all university community members to create a culture of caring. If there is a concern about the physical or mental well-being of a student, please visit the WashU Cares website (https://students.wustl.edu/washu-cares/) to file a report.

The Writing Center. The Writing Center — a free service — offers writing support to all Washington University undergraduate and graduate students. Tutors will read and discuss any kind of work in progress, including student papers, senior theses, application materials, dissertations and oral presentations. The Writing Center staff is trained to work with students at any stage of the writing process, including brainstorming, developing and clarifying an argument, organizing evidence, and improving style. Rather than editing or proofreading, tutors will emphasize the process of revision and teach students how to edit their own work.

The Writing Center is located in Mallinckrodt Center on the lower level. Appointments (http://writingcenter.wustl.edu) are preferred and can be made online, but walk-ins will be accepted if tutors are available.

Student Health and Well-Being Services, Danforth Campus

The Habif Health and Wellness Center provides medical, psychiatric, and health promotion services for undergraduate and graduate students on the Danforth Campus. Please visit the Habif Health and Wellness Center website (https://students.wustl.edu/habif-health-wellness-center/) for more information about Habif's services and staff members.

Hours:
Monday, Tuesday, Thursday, and Friday: 8 a.m. - 5 p.m.
Wednesday: 10 a.m. - 5 p.m.
Saturday, Sunday, and university holidays: Closed

For after-hours care, students should access TimelyCare (https://students.wustl.edu/timelycare/).

Medical Services

Medical Services staff members provide care for the evaluation and treatment of an illness or injury, preventive health care and health education, immunizations, nutrition counseling, and travel medicine and sexual health services. Psychiatry Services staff provide ongoing medication management for students to address their mental health concerns. Habif Health and Wellness Center providers are participating members of the Washington University in St. Louis Physician's Network. Any condition requiring specialized medical services will be referred to an appropriate specialist. Habif accepts health insurance plans that have met waiver criteria for the student health insurance plan and will be able to bill the plan according to plan benefits. The student health insurance plan requires a referral for medical care any time care is not provided at Habif (except in an emergency). Call 314-935-6666 or visit the Habif website to schedule an appointment (https://students.wustl.edu/habif-health-wellness-center/).

Appointments are also available for the assessment and referral of students who are struggling with substance abuse.

Quadrangle Pharmacy, located in the Habif Health and Wellness Center, is available to all Washington University students and their dependents. The pharmacy accepts most prescription insurance plans; students should check with the pharmacist to see if their prescription plan is accepted at the pharmacy.

The Habif Health and Wellness Center lab provides full laboratory services. Some tests can be performed in house. The remainder of all testing that is ordered by Habif is completed by LabCorp. LabCorp serves as Habif's reference lab, and it is a preferred provider on the student health insurance plan. This lab can perform any test ordered by Habif providers or outside providers.

All incoming students must provide proof of immunization for measles, mumps, and rubella (i.e., two vaccinations after the age of one year old; a titer may be provided in lieu of the immunizations). Proof of receiving a meningococcal vaccine is required for all incoming undergraduate students. A TB test in the past six months is required for students entering the university who screen positive on the TB questionnaire found on the student portal. It is also recommended that, during the five years before beginning their studies at Washington University, all students will have received the tetanus diphtheria immunization, the hepatitis A vaccine series, the hepatitis B vaccine series, the HPV vaccine series, the meningitis B vaccine, and the varicella vaccine. Medical history forms (https://students.wustl.edu/habif-health-wellness-center/) are available online. Failure to complete the required forms will delay a student's registration and prevent their entrance into housing assignments. Please visit the Habif website for complete information about immunization requirements and deadlines (https://students.wustl.edu/immunizations/).

Health Promotion Services

Health Promotion Services staff and Peer Health Educators provide free programs and risk reduction information related to mental health, sexual health, alcohol/other drugs, and community care. For more information, visit the Zenker Wellness Suite in Sumers Recreation Center and the Health and Wellness Digital Library (https://students.wustl.edu/health-wellness-digital-library/), follow Habif on Instagram (https://www.instagram.com/) (@washu_habif), and/or email wellness@wustl.edu. In 2018, this department launched the WashU Recovery Group to provide an opportunity for students in recovery from substance use to connect with other students with similar experiences. The group provides local resources, support, meetings, and activities. Members have 24/7 access to a private facility to study, meet, and socialize. The group is not a recovery program; it is a confidential resource that students can add to their support system. For more information, email recovery@wustl.edu.

Mental Health Services

Hours:
Monday, Tuesday, Thursday, and Friday: 8 a.m. - 5 p.m.
Wednesday: 10 a.m. - 5 p.m.
Saturday, Sunday, and university holidays: Closed

For after-hours mental health support, students should access TimelyCare (https://students.wustl.edu/timelycare/).

Licensed professional staff members work with students to resolve personal and interpersonal difficulties, including conflicts with or worry about friends or family, concerns about eating or drinking patterns, and feelings of anxiety and depression. Services include individual, group, and couples counseling; crisis counseling; and referral for off-campus counseling when students' needs can be better met outside of Mental Health Services. Providers also offer self-help programs including Therapy Assistance Online (TAO) (https://students.wustl.edu/therapy-assistance-online/) as well as quick consultations called "Let's Talk." All full-time students who pay the university health and wellness fee as part of their tuition are eligible for services. Visit the Mental Health Services website (https://students.wustl.edu/mental-health-services/) or call 314-935-6695 to schedule an appointment during business hours. For additional information, visit the Mental Health Services website (https://students.wustl.edu/mental-health-services/) or send an email to mhscoordinator@wustl.edu.

Important Information About Health Insurance and Fees for Danforth Campus Students

All full-time, degree-seeking Washington University students are automatically enrolled in the Student Health Insurance Plan upon completion of registration. Students may opt out of this coverage and receive a refund of the health insurance fee if they provide proof of existing comprehensive insurance coverage that meets all university requirements. Information concerning opting out of the student health insurance plan (https://students.wustl.edu/habif-health-wellness-center/) can be found online after June 1 of each year. All students must request to opt out by September 5 of every year in which they wish to be removed from the Student Health Insurance Plan. Habif provides billing services to many of the major insurance companies in the United States. Specific fees and copays apply to students using Medical Services and Mental Health Services; these fees may be billable to the students' insurance plans. More information is available on the Habif Health and Wellness Center website (https://students.wustl.edu/habif-health-wellness-center/). In addition, WashU has a health and wellness fee designed to improve the health and well-being of the campus community. It is assessed by the university, and it is entirely separate from health insurance. It covers a membership to the Sumers Recreation Center, health education, prevention efforts, and other benefits, including no-cost counseling visits.

Student Health Services, Medical Campus

For information about student health services on the Medical Campus, please visit the Student & Occupational Health Services page (https://wusmhealth.wustl.edu/students/) of the School of Medicine website.

Campus Security

The Washington University campus is among the most attractive in the nation, and it enjoys a safe and relaxed atmosphere. Personal safety and the security of personal property while on campus is a shared responsibility. Washington University has made safety and security a priority through our commitment to a full-time professional police department, the use of closed-circuit television, card access, extensive lighting initiatives based on Crime Prevention Through Environmental Design (CPTED) practices, shuttle services, emergency telephones, and ongoing educational safety awareness programs. The vast majority of crimes that occur on college campuses are crimes of opportunity, which can be prevented.

The best protection against crime is an informed and alert campus community. Washington University has developed several programs to help make everyone's experiences here safe and secure. An extensive network of emergency telephones — including more than 200 "blue light" telephones — is connected directly to the University Police Department and can alert the police to a person's exact location. In addition to the regular shuttle service, an evening student walking/mobile escort service known as "Bear Patrol" and a mobile Campus Circulator shuttle are available on the Danforth Campus.

The Campus2Home shuttle will provide a safe ride home for those living in four designated areas off campus — Skinker-DeBaliviere, Loop South, north of the Loop, and just south of the campus — from 7:00 p.m. to 4:00 a.m. seven days a week. The shuttle leaves from the Mallinckrodt Bus Plaza and Forsyth/Goldfarb Hall Center every 15 minutes from 7:00 p.m. to 1:00 a.m. and at the top (:00) and bottom (:30) of the hour from 1:00 a.m. to 4:00 a.m. The shuttle takes passengers directly to the front doors of their buildings. Shuttle drivers will then wait and watch to make sure passengers get into their buildings safely. Community members can track the shuttle in real time using the WUSTL Mobile App. The app can be downloaded free of charge from the Apple iTunes Store or the Google Play Store.

The University Police Department is a full-service organization staffed by certified police officers who patrol the campus 24 hours a day throughout the entire year. The department offers a variety of crime prevention programs, including a high-security bicycle lock program, free personal-safety whistles, computer security tags, personal safety classes, and security surveys. Community members are encouraged to download and install the WashU Safe personal safety app (https://qrco.de/bdJl4z/) on their phones; this app allows users to call for help during emergencies, to use Friend Walk to track their walks on and off campus, and to access many additional safety features. For more information about these programs, visit the Washington University Police Department website (https://police.wustl.edu/).

In compliance with the Campus Crime Awareness and Security Act of 1990, Washington University publishes an annual report (http://police.wustl.edu/clery-reports-logs/) entitled *Safety & Security: Guide for Students, Faculty, and Staff — Annual Campus Security and Fire Safety Reports and Drug & Alcohol Abuse Prevention Program*. This report is available to all current and prospective students on the Danforth Campus and to university employees on the Danforth, North and West campuses. To request a hard copy, contact the Washington University Police Department, CB 1038, One Brookings Drive, St. Louis, MO 63130-4899, 314-935-9011.

For information regarding protective services at the School of Medicine, please visit the Campus Safety page (https://facilities.med.wustl.edu/security-new/) of the Washington University Operations & Facilities Management Department.

University Policies

Washington University has various policies and procedures that govern our faculty, staff and students. Highlighted below are several key policies of the university. Web links to key policies and procedures are available on the Office of the University Registrar website (http://registrar.wustl.edu) and on the university's Compliance and Policies page (http://wustl.edu/policies/). Please note that the policies identified on these websites and in this *Bulletin* do not represent an entire repository of university policies, as schools, offices and departments may implement policies that are not listed. In addition, policies may be amended throughout the year.

Nondiscrimination Statement

Washington University encourages and gives full consideration to all applicants for admission, financial aid and employment. The university does not discriminate in access to, treatment during, or employment in its programs and activities on the basis of race, color, age, religion, sex, sexual orientation, gender identity or expression, national origin, veteran status, disability or genetic information.

Policy on Discrimination and Harassment

Washington University is committed to having a positive learning and working environment for its students, faculty and staff. University policy prohibits discrimination on the basis of race, color, age, religion, sex, sexual orientation, gender identity or expression, national origin, veteran status, disability or genetic information. Harassment based on any of these classifications is a form of discrimination; it violates university policy and will not be tolerated. In some circumstances, such discriminatory harassment may also violate federal, state or local law. A copy of the Policy on Discrimination and Harassment (http://hr.wustl.edu/policies/Pages/DiscriminationAndHarassment.aspx) is available on the Human Resources website.

Sexual Harassment

Sexual harassment is a form of discrimination that violates university policy and will not be tolerated. It is also illegal under state and federal law. Title IX of the Education Amendments of 1972 prohibits discrimination based on sex (including sexual harassment and sexual violence) in the university's educational programs and activities. Title IX also prohibits retaliation for asserting claims of sex discrimination. The university has designated the Title IX Coordinator identified below to coordinate its compliance with and response to inquiries concerning Title IX.

For more information or to report a violation under the Policy on Discrimination and Harassment, please contact the following individuals:

Discrimination and Harassment Response Coordinator

Apryle Cotton, Assistant Vice Chancellor for Human Resources
Section 504 Coordinator
Phone: 314-362-6774
apryle.cotton@wustl.edu

Title IX Coordinator

Jessica Kennedy, Director of Title IX Office
Title IX Coordinator
Phone: 314-935-3118
jwkennedy@wustl.edu

You may also submit inquiries or a complaint regarding civil rights to the United States Department of Education's Office of Civil Rights at 400 Maryland Avenue, SW, Washington, DC 20202-1100; by visiting the U.S. Department of Education website (https://www.ed.gov/); or by calling 800-421-3481.

Student Health

Drug and Alcohol Policy

Washington University is committed to maintaining a safe and healthy environment for members of the university community by promoting a drug-free environment as well as one free of the abuse of alcohol. Violations of the Washington University Drug and Alcohol Policy (https://hr.wustl.edu/items/drug-and-alcohol-policy/) will be handled according to existing policies and procedures concerning the conduct of faculty, staff, and students. This policy is adopted in accordance with the Drug-Free Workplace Act and the Drug-Free Schools and Communities Act.

Tobacco-Free Policy

Washington University is committed to providing a healthy, comfortable and productive work and learning environment for all students, faculty and staff. Research shows that tobacco use in general, including smoking and breathing secondhand smoke, constitutes a significant health hazard. The university strictly prohibits all smoking and other uses of tobacco products within all university buildings and on university property, at all times. A copy of our complete Tobacco-Free Policy (https://hr.wustl.edu/items/tobacco-free-policy/) is available on the Human Resources website.

Medical Information

Entering students in Danforth Campus programs must provide medical information to the Habif Health and Wellness Center. This will include the completion of a health history and a record of all current immunizations.

If students fail to comply with these requirements (https://students.wustl.edu/immunizations/) prior to registration, they will be required to obtain vaccinations for measles, mumps and rubella at the Habif Health and Wellness Center, if there is no evidence of immunity. In addition, undergraduate students will be required to obtain meningitis vaccinations. Students will be assessed the cost of the vaccinations. Students will be unable to complete registration for classes until all health requirements have been satisfied.

Noncompliant students may be barred from classes and from all university facilities, including housing units, if in the judgment of the university their continued presence would pose a health risk to themselves or to the university community.

Medical and immunization information is to be given via the student portal on the Habif Health and Wellness Center (https://students.wustl.edu/habif-health-wellness-center/) website. All students who have completed the registration process should access the student portal on the website. Students should fill out the form and follow the instructions for transmitting it to the Habif Health and Wellness Center. Student information is treated securely and confidentially.

Entering students in Medical Campus programs must follow the requirements as outlined on the Washington University School of Medicine Student Health Services (https://studenthealth.med.wustl.edu/students/new-students/student-entrance-requirements/) website.

Student Conduct

The Student Conduct Code sets forth community standards and expectations for Washington University students. These community standards and expectations are intended to foster an environment conducive to learning and inquiry. Freedom of thought and expression is essential to the university's academic mission.

Disciplinary proceedings are meant to be informal, fair and expeditious. Charges of non-serious misconduct are generally heard by the student conduct officer. With limited exceptions, serious or repeated allegations are heard by the campuswide Student Conduct Board or the University Sexual Assault Investigation Board where applicable.

Complaints against students that include allegations of sexual assault or certain complaints that include allegations of sexual harassment in violation of the Student Conduct Code are governed by the procedures found in the University Sexual Assault Investigation Board Policy (https://wustl.edu/about/compliance-policies/governance/usaib-procedures-complaints-sexual-assault-filed-students/), which is available online or in hard copy from the Title IX coordinator or the director of Student Conduct and Community Standards.

Students may be accountable to both governmental authorities and to the university for acts that constitute violations of law and the Student Conduct Code.

For a complete copy of the Student Conduct Code (https://wustl.edu/about/compliance-policies/academic-policies/university-student-judicial-code/), visit the university website.

Undergraduate Student Academic Integrity Policy

Effective learning, teaching and research all depend upon the ability of members of the academic community to trust one another and to trust the integrity of work that is submitted for academic credit or conducted in the wider arena of scholarly research. Such an atmosphere of mutual trust fosters the free exchange of ideas and enables all members of the community to achieve their highest potential.

In all academic work, the ideas and contributions of others must be appropriately acknowledged, and work that is presented as original must be, in fact, original. Faculty, students and administrative staff all share the responsibility of ensuring the honesty and fairness of the intellectual environment at Washington University.

Scope and Purpose

This statement on academic integrity applies to all undergraduate students at Washington University. Graduate students are governed by policies in each graduate school or division. All students are expected to adhere to the highest standards of behavior. The purpose of the statement is twofold:

1. To clarify the university's expectations with regard to undergraduate students' academic behavior; and
2. To provide specific examples of dishonest conduct. The examples are only illustrative, *not* exhaustive.

Violations of This Policy Include but Are Not Limited to the Following:

1. **Plagiarism**
   Plagiarism consists of taking someone else's ideas, words or other types of work product and presenting them as one's own. To avoid plagiarism, students are expected to be attentive to proper methods of documentation and acknowledgment. To avoid even the suspicion of plagiarism, a student must always do the following:
   - Enclose every quotation in quotation marks and acknowledge its source.
   - Cite the source of every summary, paraphrase, abstraction or adaptation of material originally prepared by another person and any factual data that is not considered common knowledge. Include the name of author, title of work, publication information and page reference.
   - Acknowledge material obtained from lectures, interviews or other oral communication by citing the source (i.e., the name of the speaker, the occasion, the place and the date).
   - Cite material from the internet as if it were from a traditionally published source. Follow the citation style or requirements of the instructor for whom the work is produced.
2. **Cheating on an Examination**
   A student must not receive or provide any unauthorized assistance on an examination. During an examination, a student may use only materials authorized by the faculty.
3. **Copying or Collaborating on Assignments Without Permission**
   When a student submits work with their name on it, this is a written statement that credit for the work belongs to that student alone. If the work was a product of collaboration, each student is expected to clearly acknowledge in writing all persons who contributed to its completion.

   Unless the instructor explicitly states otherwise, it is dishonest to collaborate with others when completing any assignment or test, performing laboratory experiments, writing and/or documenting computer programs, writing papers or reports, or completing problem sets.

   If the instructor allows group work in some circumstances but not others, it is the student's responsibility to understand the degree of acceptable collaboration for each assignment and to ask for clarification, if necessary.

   To avoid cheating or unauthorized collaboration, a student should never do any of the following:
   - Use, copy or paraphrase the results of another person's work and represent that work as one's own, regardless of the circumstances.
   - Refer to, study from or copy archival files (e.g., old tests, homework, solutions manuals, backfiles) that were not approved by the instructor.
   - Copy another's work or permit another student to copy one's work.
   - Submit work as a collaborative effort if they did not contribute a fair share of the effort.
4. **Fabrication or Falsification of Data or Records**
   It is dishonest to fabricate or falsify data in laboratory experiments, research papers or reports or in any other circumstances; to fabricate source material in a bibliography or "works cited" list; or to provide false information on a résumé or other document in connection with academic efforts. It is also dishonest to take data developed by someone else and present them as one's own. Examples of falsification include the following:

- Altering information on any exam, problem set or class assignment being submitted for a re-grade.
- Altering, omitting or inventing laboratory data to submit as one's own findings. This includes copying laboratory data from another student to present as one's own; modifying data in a write-up; and providing data to another student to submit as one's own.

5. **Other Forms of Deceit, Dishonesty or Inappropriate Conduct**
Under no circumstances is it acceptable for a student to do any of the following:
    - Submit the same work, or essentially the same work, for more than one course without explicitly obtaining permission from all instructors. A student must disclose when a paper or project builds on work completed earlier in their academic career.
    - Request an academic benefit based on false information or deception. This includes requesting an extension of time, a better grade or a recommendation from an instructor.
    - Make any changes (including adding material or erasing material) on any test paper, problem set or class assignment being submitted for a re-grade.
    - Willfully damage the efforts or work of other students.
    - Steal, deface or damage academic facilities or materials.
    - Collaborate with other students planning or engaging in any form of academic misconduct.
    - Submit any academic work under someone else's name other than one's own. This includes but is not limited to sitting for another person's exam; both parties will be held responsible.
    - Engage in any other form of academic misconduct not covered here.

This list is not intended to be exhaustive. To seek clarification, students should ask the professor or the assistant in instruction for guidance.

Reporting Misconduct

Faculty Responsibility

Faculty and instructors are strongly encouraged to report incidents of student academic misconduct to the academic integrity officer in their school or college in a timely manner so that the incident may be handled fairly and consistently across schools and departments. Assistants in instruction are expected to report instances of student misconduct to their supervising instructors. Faculty members are expected to respond to student concerns about academic dishonesty in their courses.

Student Responsibility

If a student observes others violating this policy, the student is strongly encouraged to report the misconduct to the instructor, to seek advice from the academic integrity officer of the school or college that offers the course in question, or to address the student(s) directly.

Exam Proctor Responsibility

Exam proctors are expected to report incidents of suspected student misconduct to the course instructor and/or the Disability Resource Center, if applicable.

Procedure

Jurisdiction

This policy covers all undergraduate students, regardless of their college of enrollment. Cases will be heard by school-specific committees according to the school in which the class is listed rather than the school in which the student is enrolled. All violations and sanctions will be reported to the student's college of enrollment.

Administrative Procedures

Individual undergraduate colleges and schools may design specific procedures to resolve allegations of academic misconduct by students in courses offered by that school, so long as the procedures are consistent with this policy and with the Student Conduct Code.

Student Rights and Responsibilities in a Hearing

A student accused of an academic integrity violation — whether by a professor, an assistant in instruction, an academic integrity officer or another student — is entitled to do the following:

- Review the written evidence in support of the charge
- Ask any questions
- Offer an explanation as to what occurred
- Present any material that would cast doubt on the correctness of the charge
- Receive a determination of the validity of the charge without reference to any past record of misconduct

When responding to a charge of academic misconduct, a student may do the following:

- Deny the charges and request a hearing in front of the appropriate academic integrity officer or committee
- Admit the charges and request a hearing to determine sanction(s)
- Admit the charges and accept the imposition of sanctions without a hearing
- Request a leave of absence from the university (however, the academic integrity matter must be resolved prior to re-enrollment)
- Request to withdraw permanently from the university with a transcript notation that there is an unresolved academic integrity matter pending

A student has the following responsibilities with regard to resolving the charge of academic misconduct:

- Admit or deny the charge. This will determine the course of action to be pursued.
- Provide truthful information regarding the charges. It is a Student Conduct Code violation to provide false information to the university or anyone acting on its behalf.

Sanctions

If Found *Not* in Violation of the Academic Integrity Policy

If the charges of academic misconduct are not proven, no record of the allegation will appear on the student's transcript.

If Found in Violation of the Academic Integrity Policy

If, after a hearing, a student is found to have acted dishonestly or if a student has admitted to the charges prior to a hearing, the school's academic integrity officer or committee may impose sanctions, including but not limited to the following:

- Issue a formal written reprimand
- Impose educational sanctions, such as completing a workshop on plagiarism or academic ethics
- Recommend to the instructor that the student fail the assignment (a given grade is ultimately the prerogative of the instructor)
- Recommend to the instructor that the student fail the course
- Recommend to the instructor that the student receive a course grade penalty less severe than failure of the course
- Place the student on disciplinary probation for a specified period of time or until defined conditions are met. The probation will be noted on the student's transcript and internal record while it is in force.
- In cases serious enough to warrant suspension or expulsion from the university, refer the matter to the Student Conduct Board for consideration.

Additional educational sanctions may be imposed. This list is not intended to be exhaustive.

Withdrawing from the course will not prevent the academic integrity officer or hearing panel from adjudicating the case, imposing sanctions or recommending grade penalties, including a failing grade in the course.

A copy of the sanction letter will be placed in the student's academic file.

Appeals

If a student believes the academic integrity officer or the committee did not conduct a fair hearing or if a student believes the sanction imposed for misconduct is excessive, they may appeal to the Student Conduct Board within 14 days of the original decision. Appeals are governed by Section VII C of the Student Conduct Code.

Records

Administrative Record-Keeping Responsibilities

It is the responsibility of the academic integrity officer in each school to keep accurate, confidential records concerning academic integrity violations. When a student has been found to have acted dishonestly, a letter summarizing the allegation, the outcome and the sanction shall be placed in the student's official file in the office of the school or college in which the student is enrolled.

In addition, each school's academic integrity officer shall make a report of the outcome of every formal accusation of student academic misconduct to the director of Student Conduct and Community Standards, who shall maintain a record of each incident.

Multiple Offenses

When a student is formally accused of academic misconduct and a hearing is to be held by an academic integrity officer, a committee, or the Office of Student Conduct and Community Standards, the person in charge of administering the hearing shall query the Office of Student Conduct and Community Standards about the student(s) accused of misconduct. The director shall provide any information in the records concerning that student to the integrity officer. Such information will be used in determining sanctions *only* if the student is found to have acted dishonestly in the present case. Evidence of past misconduct may not be used to resolve the issue of whether a student has acted dishonestly in a subsequent case.

Reports to Faculty and Student Body

School and college academic integrity officers are encouraged to make periodic (at least annual) reports to the students and faculty of their school concerning accusations of academic misconduct and the outcomes, without disclosing specific information that would allow identification of the student(s) involved.

Graduate Student Academic Integrity Policies

For graduate student academic integrity policies, please refer to each individual graduate school.

Statement of Intent to Graduate

Students are required to file an Intent to Graduate via WebSTAC (https://acadinfo.wustl.edu/) prior to the semester in which they intend to graduate. Additional information is available from school dean's offices and the Office of the University Registrar (http://registrar.wustl.edu).

Student Academic Records and Transcripts

Under the Family Educational Rights and Privacy Act of 1974 (FERPA) — Title 20 of the United States Code, Section 1232g, as amended — current and former students of the university have certain rights with regard to their educational records. Washington University's FERPA policy is available via the Office of the University Registrar's website (http://registrar.wustl.edu).

All current and former students may request official Washington University transcripts from the Office of the University Registrar via either WebSTAC (if they remember their WUSTL Key) or Parchment (if they do not have or cannot remember their WUSTL Key). Students may print unofficial transcripts for their personal use from WebSTAC. Instructions and additional information are available on the Office of the University Registrar's website (http://registrar.wustl.edu).

Washington University does not release nor certify copies of transcripts or other academic documents received from other schools or institutions. This includes test score reports and transcripts submitted to Washington University for purposes of admission or evaluation of transfer credit.

University Affiliations

Please click the arrows below for listings of the accrediting organizations and memberships of the different areas of the university.

Additional information about professional and specialized accreditation can be found on the Office of the Provost website (https://provost.wustl.edu/assessment/accreditors/).

Washington University in St. Louis

Accreditation

- Higher Learning Commission (https://www.hlcommission.org/)

Memberships

- American Academy of Arts & Sciences (https://www.amacad.org/)
- American Association of Colleges & Universities (https://www.aacu.org/)
- American Council of Learned Societies (https://www.acls.org/)
- American Council on Education (https://www.acenet.edu/)
- Association of American Universities (https://www.aau.edu/)
- Hispanic Association of Colleges and Universities (https://www.hacu.net/)
- Independent Colleges and Universities of Missouri (https://www.independentcollegesanduniversitiesofmo.com/)
- National Association of Independent Colleges and Universities (https://www.naicu.edu/)
- National Council for State Authorization Reciprocity Agreements (https://nc-sara.org/)
- Universities Research Association (https://www.ura-hq.org/)

College of Arts & Sciences

Memberships

- American Camp Association (https://www.acacamps.org/)
- Association for Pre-College Program Directors (https://www.precollegeassociation.org/)
- Association of University Summer Sessions (https://www.theauss.org/)
- Diversity Abroad (https://diversitynetwork.org//)
- Forum on Education Abroad (https://forumea.org/)
- Higher Education Protection Network (https://www.higheredprotection.org/)
- International Center for Academic Integrity (https://www.academicintegrity.org/)
- International Educational Exchange (http://www.ieexchanges.com/)
- Midwest Association of Pre-Law Advisors (https://mapla.org/)
- National Academic Advising Association (https://nacada.ksu.edu/)
- National Association of Advisors for the Health Professions (https://www.naahp.org/)
- National Association of Fellowships Advisors (https://nafadvisors.org/)
- North American Association of Summer Sessions (https://naass.org/)
- Professional and Organizational Development Network (https://podnetwork.org/)

Office of Graduate Studies, Arts & Sciences

Memberships

- Association of Graduate Schools (https://www.aau.edu/taxonomy/term/446/)
(Founding member)
- Council of Graduate Schools (https://cgsnet.org/)
(Founding member)
- Student Affairs Administrators in Higher Education (https://www.naspa.org/home/)

Sam Fox School of Design & Visual Arts

Accreditation — College of Art

- National Association of Schools of Art & Design (https://nasad.arts-accredit.org/)
(Founding member)

Accreditation — College of Architecture

- Master of Architecture: National Architectural Accrediting Board (https://www.naab.org/)
- Master of Landscape Architecture: Landscape Architectural Accreditation Board (https://www.asla.org/accreditationlaab.aspx)

Membership — College of Architecture

- Association of Collegiate Schools of Architecture (https://www.acsa-arch.org/)

Accreditation — Mildred Lane Kemper Art Museum

- American Alliance of Museums (https://www.aam-us.org/)

Membership — Mildred Lane Kemper Art Museum

- Association of Academic Museums and Galleries (https://www.aamg-us.org/)
- Association of Art Museum Directors (https://aamd.org/)
- College Art Association (https://www.collegeart.org/)

Olin Business School

Accreditation

- Association of MBAs (https://www.associationofmbas.com/)
- Association to Advance Collegiate Schools of Business International (https://www.aacsb.edu/)
(Charter member since 1921)
- EQUIS (https://www.efmdglobal.org/accreditations/business-schools/equis/)

McKelvey School of Engineering

Accreditation

- In the McKelvey School of Engineering, many of the undergraduate degree programs are accredited by the Engineering Accreditation Commission of ABET (http://abet.org/).

Membership

- American Society for Engineering Education (https://www.asee.org/)

School of Law

Accreditation

- American Bar Association (https://www.americanbar.org/)

Memberships

- American Association of Law Libraries (https://www.aallnet.org/)
- American Society of Comparative Law (https://ascl.org/)
- American Society of International Law (https://www.asil.org/)
- Association of Academic Support Educators (https://associationofacademicsupporteducators.org/)
- Association of American Law Schools (https://www.aals.org/)
- Central States Law Schools Association (http://cslsa.us/)
- Clinical Legal Education Association (https://www.cleaweb.org/)
- Equal Justice Works (https://www.equaljusticeworks.org/)
- Mid-America Association of Law Libraries (https://maall.wildapricot.org/)
- Mid-America Law Library Consortium (https://mallco.libguides.com/)
- National Association for Law Placement (https://www.nalp.org/)
- National Association of Law Student Affairs Professionals (https://www.nalsap.org/)
- Southeastern Association of Law Schools (https://sealslawschools.org/)

School of Medicine

Accreditation

- Liaison Committee on Medical Education (https://www.aamc.org/services/first-for-financial-aid-officers/lcme-accreditation/)

Membership

- Association of American Medical Colleges (https://www.aamc.org/)

Brown School

Accreditation

- Council on Education for Public Health (https://ceph.org/)
- Council on Social Work Education (https://www.cswe.org/)

School of Continuing & Professional Studies

Memberships

- American Association of Collegiate Registrars and Admissions Officers (https://www.aacrao.org/)
- International Center for Academic Integrity (https://www.academicintegrity.org/)
- National Academic Advising Association (https://nacada.ksu.edu/)
- National Association of Advisors for the Health Professions (https://www.naahp.org/)
- National Association of Student Personnel Administrators (https://www.naspa.org/)
- University Professional and Continuing Education Association (https://upcea.edu/)

Note: Business-related programs in the School of Continuing & Professional Studies are not accredited by the Association to Advance Collegiate Schools of Business International (https://www.aacsb.edu/).

University Libraries

Membership

- Association of Research Libraries (https://www.arl.org/)

University PhD Policies & Requirements

Academic PhD Programs

The following policies and practices apply to all PhD students regardless of school affiliation. They are specific to PhD program administration and experience. Schools may set stricter standards but must not relax these. This list does not include those policies and practices that apply to the student community as a whole (e.g., the University Student Conduct Code).

Academic and Professional Integrity for PhD Students

The Academic and Professional Integrity Policy for PhD Students (PDF) (http://bulletin.wustl.edu/pdf/Academic and Professional Integrity Policy for PhD Students_2022.pdf) continues to apply to all PhD students on the Danforth and Medical campuses, including dual-degree students when one of the degree programs is a PhD program.

Involuntary Leave of Absence

The Involuntary Leave of Absence Policy (https://wustl.edu/about/compliance-policies/governance/involuntary-leave-policy-undergraduate-students/) that applies to undergraduates was adopted to apply to all PhD students in 2014.

Financial Policies & Practices

Academic Load Status for Financial Aid, Immigration and Enrollment Verification

Graduate (Fall, Spring):

Status	Enrolled Units of Credit
Full time	9+ units
Half time	4.5-8.99 units
Less than half time	Fewer than 4.5 units

Graduate (Summer):

Status	Enrolled Units of Credit
Full time	6+ units
Half time	3-5.99 units
Less than half time	Fewer than 3 units

Certain courses may, due to appropriate curriculum and monitoring circumstances, be encoded to carry a load value higher than the actual academic credit awarded. Examples include certain engineering co-op experiences, doctoral research study and select clinical or practicum courses.

Child Daycare Subsidy

Sponsored by Washington University in St. Louis, the purpose of the Child Daycare Subsidy is to help PhD student families meet the costs of child daycare while they pursue their studies.

The amount of Child Daycare Subsidy awarded to eligible applicants is based on their financial need, the number of children they have enrolled in child daycare facilities, their child daycare expenses, and available funding. Eligible students can expect the following:

- For one child, the maximum award is $3,550 per semester.
- For two children, the maximum award is $4,550 per semester.
- For three or more children, the maximum award is $5,550 per semester.

The subsidy amount cannot exceed the cost of the daycare facility.

The application is available on the Office of the Provost website (https://provost.wustl.edu/vpge/phd-education-and-governance/).

Interdisciplinary Courses

PhD students can speak with their advisors with regard to enrolling in individual courses available outside of their school that may advance their research or professional goals. A university tuition agreement signed by all of the deans of the university's graduate and professional schools fosters interdisciplinary study across the schools and allows enrollment in classes outside of the student's home school. Many undergraduate and graduate courses are available for graduate student enrollment, subject to the following eligibility guidelines:

- The student must be enrolled full-time in a graduate degree program and have the approval of their faculty advisor or administrative officer to take a course outside of their home school.
- Courses will be open to students outside of the discipline only if those students have met the required prerequisites and have the approval of both their department/advisor and the course instructor.
- Finally, courses in the evening divisions, including the School of Continuing & Professional Studies, are not part of this agreement. Courses that require individualized instruction and/or additional fees (e.g., independent studies, individual music lessons) are also excluded.

Minimum Stipend Award

The amounts and vehicles of financial support for graduate students are usually decided by the individual schools. Washington University is committed to funding most PhD students for five to six years, depending on the time needed to complete a particular program. Funding typically consists of full tuition remission and a stipend to defray living expenses. Monetary support may come from the university or from outside sources, and it is usually administered by an administrative staff member of the program or the school acting in accordance with instructions received from the program/school administration or from a faculty member.

New Child Leave

Full-time PhD students may request a New Child Leave to assume care for a new child. They should maintain their full-time student status. Students on New Child Leave are not expected to participate in mentored teaching or research experience for up to 60 calendar days while they receive their current stipend support. Additional time off without receiving a stipend for up to a full semester will ordinarily be granted by the student's home school if approved by the student's department.

New Child Leave does not affect the student's full-time status and will not appear on the student's official transcript. New child leave must be taken within the first year after the child's birth or adoption. Students should contact their department to request a New Child Leave.

Students who receive support from external agencies should consult the policies and guidelines of the sponsor.

PhD General Requirements

To earn a PhD at Washington University, a student must complete all courses required by their department/program; maintain satisfactory academic progress; pass certain examinations; fulfill residence and mentored experience requirements; write, defend, and submit a dissertation; and file an Intent to Graduate form via WebSTAC (https://acadinfo.wustl.edu).

Residence Requirement

Each PhD student must spend at least one academic year enrolled full-time at Washington University. Any exceptions must be approved by the dean of the student's respective school and the Vice Provost for Graduate Education.

Program Length Limit

The maximum number of semesters of continuous enrollment is 18 (9 years). Students in PhD programs who have not completed their terminal degrees and who have not withdrawn will be dismissed at the end of 18 semesters. An exception may be granted by the dean of the student's respective school on request by the designated faculty graduate program director (in most departments, this position is called the *Director of Graduate Studies*) if the student is expected to complete their degree during a tenth year of enrollment. Enrollment for an eleventh continuous year will not be allowed. Semesters during which the student is on an approved leave of absence are not included on the enrollment clock.

Qualifying Examinations

Progress toward the PhD is contingent upon the student passing examinations that are variously called preliminary, qualifying, general, comprehensive or major field exams. The qualifying process varies according to the program. In some programs, it consists of a series of incremental, sequential and cumulative exams over a considerable time. In others, the exams are held during a relatively short period of time. Exams may be replaced by one or more papers. The program, which determines the structure and schedule of the required examinations, is responsible for notifying the school registrar or the appropriate record custodian of the student's outcome, whether successful or unsuccessful.

Mentored Experience Requirement

PhD students at Washington University must complete a department-defined Mentored Experience. The Mentored Experience Requirement is a doctoral degree milestone that is notated on the student's transcript when complete. Each department has an established Mentored Experience Implementation Plan in which the number of semesters that a student must engage in a Mentored Teaching Experience or a Mentored Professional Experience is defined. The Mentored Experience Implementation Plans outline how doctoral students within the discipline will be mentored to achieve competencies in teaching at basic and advanced levels. Some departments may elect to include the

Mentored Professional Experiences as an avenue for completing one or more semesters of the Mentored Experience Requirement. Doctoral students will enroll in Mentored Teaching Experiences or Mentored Professional Experiences to signify their progression toward completing the overall Mentored Experience Requirement for their degree.

Dissertation

As evidence of the mastery of a specific field of knowledge and of the capacity for original scholarly work, each candidate must complete a dissertation. Each PhD candidate will form a Research Advisory Committee (RAC) approved by their department or program and by their school's graduate program oversight body. The RAC will approve the subject and approach of the dissertation, which will be evidenced by the student's completion of the Title, Scope and Procedure requirement.

The RAC should consist of at least three full-time Washington University faculty members who are authorized to supervise PhD students and who have appropriate expertise in the proposed field of study. One of these faculty members must be the student's primary research advisor/mentor. Additional members, including external members with active research programs at outside institutions, may serve on the RAC subject to approval by the school's graduate program oversight body.

- For cross-school/interdisciplinary PhD programs, the approvals referenced above should be obtained from the graduate program oversight body of the school of the primary research advisor/mentor.
- For a PhD program offered in partnership with an external academic institution, one full-time faculty member of the partner institution who is authorized to supervise PhD students and who has appropriate expertise in the proposed field of study may serve on the RAC as part of the three-member minimum requirement.

A Title, Scope and Procedure form for the dissertation must be signed by the RAC members and by the program chair. It must be submitted to the school registrar or the appropriate record custodian at least six months before the degree is expected to be conferred or before the beginning the fifth year of full-time enrollment, whichever is earlier.

A Doctoral Dissertation Guide and a template that provides instructions regarding the format of the dissertation are available through the website of the Office of the Provost (https://provost.wustl.edu/vpge/phd-education-and-governance/); both of these should be read carefully at every stage of dissertation preparation.

Each student is required to make the full text of the dissertation available to the committee members for their review at least one week before the dissertation defense. Most degree programs require two or more weeks for the review period; students should check their program's policies.

Dissertation Defense

Approval of the written dissertation by the Research Advisory Committee (RAC) is strongly recommended before the student can orally defend the dissertation. The doctoral dissertation committee that examines the student during the defense consists of at least five members. Normally, the members of the RAC also serve on the doctoral dissertation committee. The dissertation committee is then additionally augmented to ensure that the following criteria are met:

1. Three of the five members (or a similar proportion of a larger committee) must be full-time Washington University faculty members or, for programs offered by Washington University–affiliated partners, full-time members of a Washington University–affiliated partner institution who are authorized to supervise PhD students and who have appropriate expertise in the proposed field of study. One of these three members must be the PhD student's primary thesis advisor, and one may be a member of the emeritus faculty.
2. All other committee members must be active in research/scholarship and have appropriate expertise in the proposed field of study whether at Washington University, at another university, in government or in industry.
3. At least one of the five members must bring expertise outside of the student's field of study to the committee, as judged by the relevant school's graduate program oversight body.

The approval processes outlined under RAC in the Doctoral Council bylaws formation also apply to the doctoral dissertation committee, including approval of each dissertation committee by the host school's graduate program oversight body/bodies.

The student is responsible for making the full text of the dissertation accessible to their committee members for their review in advance of the defense according to program rules. Faculty outside of the committee and graduate students who are interested in the subject of the dissertation are normally welcome to attend all or part of the defense but may ask questions only at the discretion of the committee chair. Although there is some variation among degree programs, the defense ordinarily focuses on the dissertation itself and its relation to the student's field of expertise.

(Policy amended by the Doctoral Council on Aug. 25, 2022)

Dissertation Submission

After the defense, the student must submit an electronic copy of the dissertation online to the university. The submission website requires students to choose among publishing and copyrighting services offered by ProQuest ETD Administrator (https://www.etdadmin.com/main/home/), but the university permits students to make whichever choices they prefer. Students are asked to submit the Survey of Earned Doctorates (https://sed-ncses.org/login.aspx) separately. The degree program is responsible for delivering the final approval form, signed by the committee members at the defense and then by the program chair or director, to the school registrar or the appropriate record custodian. Students who defend their dissertations successfully have not completed their PhD requirements; they finish earning their degree only when their dissertation submission has been accepted by their school of record.

McKelvey School of Engineering

The McKelvey School of Engineering at Washington University in St. Louis consists of six academic departments and three interdisciplinary PhD programs offering both master's and doctoral degrees in a wide range of engineering disciplines.

We offer master's, master's of science (MS) and master's of engineering (MEng) degrees, many of which can be completed on either a full-time or part-time basis. We also offer a large number of full-time doctor of philosophy (PhD) degrees and some part-time doctor of science (DSc) degree options.

Our mission is to promote independent inquiry in engineering research and education with an emphasis on scientific excellence, innovation and collaboration without boundaries. McKelvey engineers produce new knowledge that changes the world, and our faculty are educating students to explore and create in a world we cannot yet imagine. Through research and education, we are making a positive impact on the local community, the country and the world.

Contact Information

McKelvey School of Engineering — Graduate Student Services
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MSC 1100-122-303
One Brookings Drive
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Website:	http://engineering.wustl.edu/

Academic Programs Offered

Fields of Study

- Biomedical Engineering (p. 27)
- Computational & Data Sciences (Interdisciplinary PhD) (p. 36)
- Computer Science & Engineering (p. 41)
- Electrical & Systems Engineering (p. 54)
- Energy, Environmental & Chemical Engineering (p. 67)
- Imaging Science (p. 74)
- Materials Science & Engineering (p. 81)
- Mechanical Engineering & Materials Science (p. 84)
- Henry Edwin Sever Institute (p. 97)

Degrees Offered

- Aerospace Engineering (MS, DSc, PhD) (p. 84)
- Biomedical Engineering (MS, PhD) (p. 27)
- Computational & Data Sciences (PhD) (p. 36)
- Computer Engineering (MS, PhD) (p. 41)
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- Construction Management (Master (p. 97), Certificate (p. 114))
- Cybersecurity Engineering (MS, Certificate) (p. 52)
- Cybersecurity Management (Master (p. 100), Online Master (p. 107), Certificate (p. 115), Online Certificate (p. 119))
- Data Mining and Machine Learning (Certificate) (p. 53)
- Electrical Engineering (MS, DSc, PhD) (p. 54)
- Energy, Environmental & Chemical Engineering (MEng, MS, PhD) (p. 67)
- Engineering Data Analytics and Statistics (MS) (p. 54)
- Engineering Management (Master (p. 102), Online Master (p. 109), Certificate (p. 116))
- Health Care Operational Excellence (Online Master (p. 112), Certificate (p. 117))
- Imaging Science & Engineering (Certificate) (p. 54)
- Imaging Science (p. 74) (MS (p. 80), Interdisciplinary PhD (p. 77))
- Information Systems Management (Master) (p. 105)
- Materials Science & Engineering (p. 84) (MS, DSc (p. 84), PhD (p. 81))
- Mechanical Engineering (MEng, MS, DSc, PhD) (p. 84)
- Systems Science & Mathematics (MS, DSc, PhD) (p. 54)

Biomedical Engineering

Biomedical engineering (BME) seeks to advance and integrate life science knowledge with engineering methods and innovations that contribute to improvements in human health and well-being. Our vision is that lasting knowledge of biomedical systems and paradigm-shifting engineering technology will arise from integrating engineering concepts and basic science knowledge from the molecular level to the whole-body level. We believe that those taught to work across multiple disciplines and to integrate modeling and experimental systems approaches will be uniquely positioned to advance and generate new disciplines in biomedical engineering.

With this vision in mind, we are committed to educating the next generation of biomedical engineers. We have leveraged our interdisciplinary strengths in engineering and clinical and life sciences to build a biomedical engineering department around research programs of excellence and translational potential: Biomedical & Biological Imaging; Cardiovascular Engineering; Cellular & Molecular Bioengineering; Neural Engineering; Orthopedic Engineering; Regenerative Engineering in Medicine; and Women's Health Technologies. These areas provide exciting opportunities for students with a variety of backgrounds and interests.

Students seeking the **Master of Science (MS) in Biomedical Engineering** will need to complete 30 course credits, which include a core curriculum. MS students pursuing the thesis option perform research on a topic approved by the research mentor. Results of the study are published in a thesis that is defended in front of a committee of faculty members prior to graduation. The results should be of quality high enough to be published as a paper in a peer-reviewed journal. A total of 30 credits can be completed in two to four semesters.

Students seeking the **PhD in Biomedical Engineering** may choose to study in one of seven multidisciplinary research programs that represent frontiers in biomedical engineering. Our core faculty work collaboratively with more than 130 affiliated faculty to offer students the opportunity to learn in a diverse and rich spectrum of BME research areas. Students graduating with the PhD in Biomedical Engineering are prepared to pursue paths in research and development in academic and industry settings, and they are also ready to contribute to teaching and research translation. The **MD/PhD in Biomedical Engineering,** which is offered jointly with the top-ranked School of Medicine, gives students in-depth training in modern biomedical research and clinical medicine. The typical MD/PhD career combines patient care and biomedical research but leans toward research.

Email:	bme@wustl.edu
Website:	https://bme.wustl.edu/academics/graduate-programs/index.html

Faculty

Chair

Lori A. Setton (https://engineering.wustl.edu/Profiles/Pages/Lori-Setton.aspx)
Lucy and Stanley Lopata Distinguished Professor of Biomedical Engineering
PhD, Columbia University
Biomaterials for local drug delivery; tissue regenerations specific to the knee joints and spine

Endowed Professor

Rohit V. Pappu (https://engineering.wustl.edu/faculty/Rohit-Pappu.html)
Gene K. Beare Distinguished Professor of Biomedical Engineering
PhD, Tufts University
Macromolecular self assembly and function; computational biophysics

Professors

Dennis L. Barbour (https://engineering.wustl.edu/faculty/Dennis-Barbour.html)
MD, PhD, Johns Hopkins University
Application of novel machine learning tools to diagnose and treat disorders of perception and cognition

Jianmin Cui (https://engineering.wustl.edu/faculty/Jianmin-Cui.html)
PhD, State University of New York–Stony Brook
Ion channels; channel structure-function relationship; biophysics

Daniel Moran (https://engineering.wustl.edu/faculty/Daniel-Moran.html)
PhD, Arizona State University
Motor control; neural engineering; neuroprosthetics; movement biomechanics

Baranidharan Raman (https://engineering.wustl.edu/faculty/Barani-Raman.html)
PhD, Texas A&M University
Computational and systems neuroscience; neuromorphic engineering; pattern recognition; sensor-based machine olfaction

Jin-Yu Shao (https://engineering.wustl.edu/faculty/Jin-Yu-Shao.html)
PhD, Duke University
Cell mechanics; receptor and ligand interactions; molecular biomechanics

Jon Silva (https://engineering.wustl.edu/faculty/Jonathan-Silva.html)
Dennis & Barbara Kessler Career Development Associate Professor
PhD, Washington University
Ion channel biophysics

Chao Zhou
PhD, University of Pennsylvania
Optical coherence tomography

Quing Zhu (https://engineering.wustl.edu/faculty/Quing-Zhu.html)
Edwin H. Murty Professor of Engineering
PhD, University of Pennsylvania
Biophotonics and multimodality ultrasound and optical imaging

Associate Professors

Hong Chen (https://engineering.wustl.edu/faculty/Hong-Chen.html)
PhD, University of Washington
Physical acoustics; therapeutic ultrasound and ultrasound imaging

Song Hu (https://engineering.wustl.edu/faculty/Song-Hu.html)
PhD, Washington University in St. Louis
Optical and photoacoustic technologies for high-resolution structural, functional, metabolic and molecular imaging in vivo

Michelle Oyen (https://engineering.wustl.edu/faculty/Michelle-Oyen.html)
PhD, University of Minnesota
Bioengineering approaches to the study of pregnancy and childbirth; mechanical properties of hydrogel and hydrogel composite materials; biomimetic materials referencing both hard and soft natural tissues

Jai S. Rudra (https://engineering.wustl.edu/faculty/Jai-Rudra.html)
PhD, Louisiana Tech University
Peptide-based biomaterials; immunoengineering; immunology of nanoscale aggregates; development of vaccines and immunotherapies

Kurt A. Thoroughman (https://engineering.wustl.edu/faculty/Kurt-Thoroughman.html)
PhD, Johns Hopkins University
Human motor control and motor learning; neural computation

Assistant Professors

Nate Huebsch (https://engineering.wustl.edu/faculty/Nathaniel-Huebsch.html)
PhD, Harvard University
Cell-material Interactions, iPSC-based tissue modeling to study cardiac development and disease

Abhinav Kumar Jha (https://engineering.wustl.edu/faculty/Abhinav-Jha.html)
PhD, University of Arizona
Development of computational-imaging solutions for diagnosing and treating diseases

Christine M. O'Brien (https://engineering.wustl.edu/faculty/Christine-OBrien.html)
PhD, Vanderbilt University
Developing optical spectroscopy and imaging tools to solve global problems in maternal-fetal health and reproductive diseases

Alexandra Rutz (https://engineering.wustl.edu/faculty/Alexandra-Rutz.html)
PhD, Northwestern University
Engineering of electronic tissues using materials design and fabrication-based approaches

Ismael Seáñez (https://engineering.wustl.edu/faculty/Ismael-Seanez.html)
PhD, California Institute of Technology
Neuro-rehabilitation tools and programs that promote active use of residual mobility and maximize recovery through the use of body-machine interfaces

Michael D. Vahey (https://engineering.wustl.edu/faculty/Michael-Vahey.html)
PhD, Massachusetts Institute of Technology
Biophysical mechanisms of infectious disease; fluorescence microscopy; microfluidics

Principal Lecturer

Patricia Widder (https://engineering.wustl.edu/faculty/Patricia-Widder.html)
MS, Washington University

Lecturer

Katherine Schreiber
PhD, Saint Louis University

Senior Professor

Larry Taber
PhD, Stanford University
Mechanics of growth and development; cardiac mechanics

Senior Emeritus Professors

Yoram Rudy
Fred Saigh Distinguished Professor of Engineering
PhD, Case Western Reserve University
Cardiac electrophysiology; modeling of the cardiac system

Frank Yin
MD, PhD, University of California, San Diego

Degree Requirements

Please visit the following pages for information about our graduate programs:

- PhD and Combined MD/PhD in Biomedical Engineering (p. 35)
- Master of Science (MS) in Biomedical Engineering (p. 35)

Courses

Below are all BME graduate-level courses. Visit online course listings to view semester offerings for E62 BME (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E62&crslvl=5:8).

E62 BME 501C BME Doctoral Seminar Series
This is a credit option for BME students who attend regularly scheduled BME seminars (or approved substitute seminars). A satisfactory grade is obtained by submission of a two-page peer-reviewed paper written by one of the regularly scheduled BME seminar speakers whose seminar the student attended. Papers are to be submitted to the Graduate Student Administrator for review by the Director of Doctoral Studies. Prerequisite: Current BME student in the second year or beyond.
Credit 1 unit.

E62 BME 505 Professional and Personal Pathways to the PhD Program
This course is designed to guide PhD students as they embark on their first year in the Biomedical Engineering program. Topics include choosing a thesis lab and mentor, creating individual development plans, career exploration, and building mentor realtionships through networking.
Credit 1 unit.

E62 BME 506 Seminar in Imaging Science and Engineering
This seminar course consists of a series of tutorial lectures on Imaging Science and Engineering with emphasis on applications of imaging technology. Students are exposed to a variety of imaging applications that vary depending on the semester, but may include multispectral remote sensing, astronomical imaging, microscopic imaging, ultrasound imaging, and tomographic imaging. Guest lecturers come from several parts of the university. This course is required of all students in the Imaging Science and Engineering program; the only requirement is attendance. This course is graded pass/fail. Prerequisite: admission to Imaging Science and Engineering program.
Same as E35 ESE 596

Credit 1 unit.

E62 BME 507 Radiological Physics and Dosimetry
This class is designed to construct a theoretical foundation for ionizing radiation dose calculations and measurements in a medical context and prepare graduate students for proper scientific presentations in the field of x-ray imaging and radiation therapy. Specifically, a student completing this course will be able to do the following: 1. Understand and apply key concepts specific to energy deposition for both ionizing photon interactions and transport in matter and for energetic charged particle interactions and transport in matter. Radiation sources include radioactivity, x-ray tubes, and linear accelerators. 2. Understand the theoretical details of ion-chamber based dosimetry and of both cavity-theory based (TG-21) and Monte-Carlo based (TG-51) clinical protocols. 3. Perform and present real-world style research projects as a group, and present these projects in a typical professional scientific format and style. 4. Achieve an appreciation of the history and potential future developments in ionizing radiation detection and dosimetry. Prerequisites: BS in physics or engineering and instructor approval.
Credit 3 units.

E62 BME 5071 Radiobiology
Effects of ionizing radiations on living cells and organisms, including physical, chemical, and physiological bases of radiation cytotoxicity, mutagenicity and carcinogenesis. Textbook: *Radiobiology for the Radiologist*. Eric Hall and Amato Giaccia. Two lectures per week. Prerequisites: graduate student standing and one year each of biology, physics and organic chemistry, or approval of instructor.
Credit 2 units.

E62 BME 5072 Radiation Therapy Physics
Ionizing radiation use in radiation therapy to cause controlled biological effects in cancer patients. Physics of the interaction of the various radiation modalities with body-equivalent materials, and physical aspects of clinical applications. Lecture and lab. Prerequisites: graduate student standing or permission of instructor.
Credit 3 units.

E62 BME 5073 Radiation Protection and Safety
This course will introduce concepts of radiation protection and safety. The focus will be on how to protect humans and environment from ionizing radiation. Special emphasis will be on radiological protection in clinics. Prerequisite: graduate student standing or permission of the instructor.
Credit 2 units.

E62 BME 519 Advanced Cognitive, Computational, and Systems Neuroscience
This course will develop critical thinking and analysis skills with regard to topics in cognitive, computational and systems neuroscience. A particular focus of the course will be aimed toward quantitative literacy, statistical methodology, and pragmatic hands-on experience with the tools and best practices needed to conduct state-of-the-art research in modern studies of brain and behavior. Complementary approaches will be emphasized, including deduction vs. induction, frequentist vs. Bayesian, cohort vs. individual, and random vs. biased sampling. Particular topics include machine learning, Big Data, reproducibility, equitable research and scientific visualization. Students will be provided with foundational and theoretical tools to ensure maximal scientific rigor in their own research by enabling them to think carefully about core issues in experimental design and about key challenges and controversies that arise in relation to hypothesis testing, statistical inference and data management. Work will be conducted in MATLAB, R or Python, and prior experience with one of these tools is highly recommended. Prerequisite: Graduate standing or permission of instructor.
Credit 3 units.

E62 BME 523 Biomaterials Science
An understanding of the interactions between biological systems and artificial materials is of vital importance in the design of medical devices. This course will introduce the principles of biomaterials science, unifying knowledge from the fields of biology, materials science, surface science, and colloid science. The course will be taught from the primary scientific literature, focusing on the study of protein/surface interactions and hydrogel materials. E37 MEMS 3610 OR MEMS 3601 OR permission of instructor
Credit 3 units. EN: TU

E62 BME 524 Tissue Engineering
This course integrates the principles and methods of engineering and life sciences toward the fundamental understanding of normal and pathological mammalian tissues especially as they relate to the development of biological substitutes to restore or improve tissue function. Current concepts and strategies including drug delivery, tissue and cell transplantation, and in vivo tissue regeneration will be introduced as well as their respective clinical applications. Prerequisites: BME 366; or MEMS 3410, Biol 2960 and 2970; or permission of the instructor.
Credit 3 units. EN: TU

E62 BME 527 Design of Artificial Organs
Medical devices that replace the function of one of the major organs in the body must usually interface with flowing blood. Examples include total artificial hearts, left ventricular assist devices, membrane oxygenators, hemodialysis systems and encapsulated endocrine cells. The design of these devices relies on integration of knowledge from a variety of fields, in particular computational fluid dynamics and blood rheology. We will study the process by which a concept for a device eventually leads to a functioning, blood-contacting medical device, with most of the focus on the design of left ventricular assist devices. Students will learn to use CAD to design blood pumping devices, test their designs via computational fluid dynamics, and 3D print and test their pumps with water. Prerequisites: BME 366 or equivalent course in transport phenomena (including momentum and mass transfer).
Credit 3 units. EN: TU

E62 BME 528 Translational Regenerative Medicine
This course provides students with an opportunity to connect basic research with applications in translation for several tissues/disease models. Course sessions will alternate between literature on basic mechanisms of development/stem cell biology and applications led by researchers or clinicians working in each area. Areas of focus will include cardiovascular development/congenital heart disease and arrhythmia, lung, endocrinology/diabetes, gut/intestinal disorders, musculoskeletal, neural (peripheral and brain), liver, hematology and eye. Emphasis on how discovery can be translated will be a major focus of the course. Students will be expected to review and present on primary literature in the field. Graduate standing is required. Prerequisites: graduate standing Engineering or DBBS.
Credit 3 units.

E62 BME 530A Molecular Cell Biology for Engineers
This course is designed for upper-level undergraduates and first-year graduate students with a background in engineering. It covers the biology of cells of higher organisms: protein structure and function; cellular membranes and organelles; cell growth and oncogenic

transformation; cellular transport, receptors, and cell signaling; and the cytoskeleton, the extracellular matrix, and cell movement. Emphasis will be placed on examples relevant to biomedical engineering. In addition to lecture material, a focus will be placed on understanding the experimental techniques used in cell biology and the critical analysis of primary literature. Note that this course does not count for engineering topics credits and that it is meant to fulfill a life science requirement for engineering or physical sciences graduate students. Prerequisites: Biol 2960 and Biol 2970 or graduate standing.
Credit 3 units.

E62 BME 532 Physics of Biopolymers and Bioinspired Polymers
This course will cover physics concepts from the statistical physics of polymers and polymer solutions to describe proteins, nucleic acids, and bioinspired polymers. Topics include statistical physics concepts, theoretical and numerical descriptions of polymers, applying these descriptions to biopolymers, the thermodynamics of polymer solutions, concepts of polymer dynamics, descriptions of polymeric materials, and advanced topics in phase transitions and molecular design. The material will be fast paced and involve rigorous mathematical descriptions, experimental design, interpretations of experimental data, and some numerical simulations. The course will be heavy on individual homework and team-based project work. Direct connections between concepts and modern topics in biology and biomaterials will be emphasized. Prerequisites: BME 320B or equivalent and a first course in transport phenomena.
Same as E62 BME 432
Credit 3 units. EN: TU

E62 BME 533 Biomedical Signal Processing
This course is designed for graduate students with little or no background in biomedical signal processing, with an emphasis on time- and frequency-domain analyses of biomedical signals and their applications to a variety of real-world biomedical problems. Technical topics of this course include a review of linear signals and systems theory, biomedical system modeling, time-domain analysis, frequency transforms, frequency-domain analysis, linear filter design, signal truncation and sampling, discrete Fourier transform, and fast Fourier transform. Application topics include noise analysis of biomedical signals and frequency analysis and machine learning in biomedical image processing. Concepts learned in class will be applied using software tools to biomedical signals such as biological rhythms, EMG, ECG, EEG, and biomedical images. Prerequisites: graduate standing or consent of instructor.
Credit 3 units. EN: TU

E62 BME 537 Computational Molecular Biology
This course is a survey of algorithms and mathematical methods in biological sequence analysis (with a strong emphasis on probabilistic methods) and systems biology. Sequence analysis topics include introduction to probability, probabilistic inference in missing data problems, hidden Markov models (HMMs), sequence alignment, and identification of transcription-factor binding sites. Systems biology topics include the mapping of gene regulatory networks, quantitative modeling of gene regulatory networks, synthetic biology, and applications of deep learning in computational biology. Prerequisite: CSE 131 or CSE 501N.
Same as E81 CSE 587A
Credit 3 units. EN: BME T, TU

E62 BME 538 Cell Signal Transduction
This course will cover the elements of cell signal transduction important to human development, homeostasis and disease. Lectures will be combined with primary literature review to cover canonical signaling and current topics within the field. Spatial, time and dose-dependent aspects of signaling will be of particular focus. Topics include G protein-coupled receptors, receptor tyrosine kinases, adhesion signaling, the MAPK cascade, lipid signaling, the DNA damage response, and autocrine, paracrine and juxtacrine signaling. Prerequisite: BME 530A or BME 5068.
Credit 3 units.

E62 BME 542 Biomacromolecules Design and Engineering
Biological macromolecules (i.e., carbohydrates, lipids, proteins, and nucleic acids) are important components of the cell and its supporting matrix that perform a wide array of functions. This course will introduce the principles and recent advances in nucleic acid/gene engineering, protein/peptide engineering, and chemical/enzymatic conjugation technologies; it will also discuss the application of engineered biomacromolecules in clinical therapeutics/diagnostics, biosensing, bioimaging, and biocatalysis. Students will learn material through lectures, reading, homework, scientific publications, and molecular visualization tools. Students will work individually or in pairs/groups to develop and lead discussions on engineering biomacromolecules and molecular characterization techniques. Prerequisite: Basic knowledge of genes and cloning.
Same as E62 BME 442
Credit 3 units. EN: TU

E62 BME 543 Molecular and Cellular Engineering
The ability to engineer biological function at the cellular level holds tremendous potential for both basic and applied science. This course aims to provide knowledge and practical proficiency in the methods available for measuring and controlling the molecular organization of eukaryotic cells. Topics to be covered include genome engineering using viral- and CRISPR-Cas systems; spatial and temporal control of proteins and their interactions; methods for characterizing and engineering post-translational modifications; and the relationship between cellular organization and function in migration, immune cell target recognition, and differentiation. Examples from recent scientific literature will provide the foundation for these topics.
Same as E62 BME 443
Credit 3 units. EN: TU

E62 BME 5430 Systems Analysis of Biological Signaling
This course covers biochemical and computational methods of cellular signaling pathway analysis. Topics include kinetics, differential equations, and sensitivity analysis, with emphasis on cellular and molecular vascular signaling in health and disease. Prerequisites: Biol 2960 and Math 217.
Credit 3 units. EN: TU

E62 BME 544 Biomedical Instrumentation
This course will include operational and instrumentation amplifiers for bioelectric event signal conditioning, interfacing and processing; instrumentation noise analysis and filter design; A/D converters and hardware and software principles as related to sampling, storing, processing, and display of biosignals; modeling, analysis, and operation of transducers, sensors, and electrodes, for physiological and imaging systems; and an introduction to ultrasound, X-ray, and optical imaging systems. In addition, students will be involved in three projects of designing and building instrumentation amplifier and filter systems, ultrasound systems, and optical systems. Prerequisites: BME 301A and BME 301B.
Same as E62 BME 444
Credit 3 units. EN: TU

E62 BME 550 Numerical Methods for Computational Modeling in Biomedicine
Advanced computational methods are required for the creation of biological models. Students will be introduced to the process of model development from beginning to end, which includes model formulation, how to solve and parameterize equations, and how to evaluate model success. To illustrate the potential of these methods, participants will systematically build a model to simulate a "real-life" biological system that is applicable to their research or interest. A mechanistic appreciation of the methods will be gained by programming the methods in a low-level language (C++) in a Linux environment. While extensive programming knowledge is not required, participants are likely to find that some programming background will be helpful. Students enrolled in the 550 graduate class will be required to complete a final project that incorporates the methods taught in class. Prerequisites: E81 131.
Same as E62 BME 450
Credit 3 units. EN: TU

E62 BME 5501 Translational Neuroengineering
This course focuses on the design of bioelectric devices for use in clinical patients. Neural stimulators (e.g., deep brain, vagal) will be the basis for a case-study approach to designing and developing new bioelectrical medical devices. This project-based course will introduce the student to the use of finite element solvers to design novel stimulators. In addition to the engineering design aspects, issues such as product liability, FDA approval, and so on will be discussed. Prerequisite: BME 471
Credit 3 units. EN: TU

E62 BME 5565 Mechanobiology of Cells and Matrices
At the interface of the cell and the extracellular matrix, mechanical forces regulate key cellular and molecular events that profoundly affect aspects of human health and disease. This course offers a detailed review of biomechanical inputs that drive cell behavior in physically diverse matrices. In particular, cytoskeletal force-generation machineries, mechanical roles of cell-cell and cell-matrix adhesions, and regulation of matrix deformations are discussed. Also covered are key methods for mechanical measurements and mathematical modeling of cellular response. Implications of matrix-dependent cell motility in cancer metastasis and embryonic development are discussed. Prerequisite: graduate standing or permission of the instructor.
Same as E37 MEMS 5565
Credit 3 units. EN: TU

E62 BME 559 Intermediate Biomechanics
This course covers several of the fundamental theories of solid mechanics that are needed to solve problems in biomechanics. The theories of nonlinear elasticity, viscoelasticity and poroelasticity are applied to a large range of biological tissues including bone, articular cartilage, blood vessels, the heart, skeletal muscle, and red blood cells. Other topics include muscle activation, the biomechanics of development and functional adaptation, and the mechanics of hearing. Prerequisites: BME 240 and ESE 318 and ESE 319 or equivalent, or permission of instructor.
Credit 3 units. EN: TU

E62 BME 562 Mechanics of Growth and Development
This course applies the fundamental principles of solid mechanics to problems involving growth, remodeling and morphogenesis of cells, tissues and organs. Introduction to developmental biology, nonlinear elasticity, viscoelasticity and active contraction. Particular topics include cellular morphogenetic mechanisms, growth and development of the cardiovascular system, and adaptive remodeling of bone. Prerequisites: BME 240 or MEMS 241 or equivalent.
Credit 3 units. EN: TU

E62 BME 564 Orthopaedic Biomechanics — Cartilage/Tendon
Basic and advanced viscoelasticity and finite strain analysis applied to the musculoskeletal system, with a primary focus on soft orthopaedic tissues (cartilage, tendon and ligament). Topics include: mechanical properties of cartilage, tendon and ligament; applied viscoelasticity theory for cartilage, tendon and ligament; cartilage, tendon and ligament biology; tendon and ligament wound healing; osteoarthritis. This class is geared to graduate students and upper-level undergraduates familiar with statics and mechanics of deformable bodies. Prerequisite: BME 240 or equivalent. *Note*: BME 590Z (BME 463/563) Orthopaedic Biomechanics — Bones and Joints is *not* a prerequisite.
Same as E37 MEMS 5564
Credit 3 units. EN: TU

E62 BME 5642 Human-Machine Interfaces
This course will provide an overview of neurorehabilitation technologies for individuals with neuromotor disorders. Topics will include the neurophysiology of human motor and sensory systems, motor control and adaptation, and neuroplasticity in the damaged brain and spinal cord. Human-machine interface systems including prostheses, orthoses and exoskeletons, wheelchairs, neuroprosthetics, brain-machine interfaces, and wearable robots will be discussed with an emphasis on their clinical applications for restoration of motor and sensory functions. Lecture material and assignments will draw from current scientific literature and research. All students will be placed on a waitlist. Registration will be split between undergraduate and graduate students. Prerequisite: BME 301 Quantitative Physiology I or equivalent introductory physiology course preferred.
Same as E62 BME 4642
Credit 3 units. EN: BME T, TU

E62 BME 565 Biosolid Mechanics
Introduction to the mechanical behaviors of biological tissues of musculoskeletal, cardiac and vascular systems. Topics to be covered include static force analysis and nonlinear optimization theory; linearly elastic models for stress-strain analysis and solutions to relevant problems in bioelasticity; models of active structures (e.g., muscles); strain energy methods and nonlinear tissue behaviors; and introductory theory for finite element analysis. Emphasis will be placed on modeling stress-strain relations with relevance to biological tissues. Prerequisites: BME 240 or equivalent and ESE 318 and ESE 319.
Same as E62 BME 465
Credit 3 units. EN: TU

E62 BME 569 Cardiac Electrophysiology
This course is an introduction to cardiac electrophysiology with an emphasis on arrhythmia mechanisms, experimental methods, and clinical applications. Topics will include modeling of cardiac arrhythmias, mapping of cardiac electric activity, pacemakers and defibrillators, and ablation of cardiac tissue.
Same as E62 BME 469
Credit 3 units. EN: TU

E62 BME 570 Mathematics of Imaging Science
This course will expose students to a unified treatment of the mathematical properties of images and imaging. This will include an introduction to linear vector space theory, operator theory on Hilbert spaces, and concepts from applied functional analysis. Further, concepts from generalized functions, Fourier analysis, and radon transform will be discussed. These tools will be applied to conduct deterministic analyses of imaging systems that are described as continuous-to-continuous, continuous-to-discrete, and discrete-to-

discrete mappings from object properties to image data. In addition, imaging systems will be analyzed in a statistical framework where stochastic models for objects and images will be introduced. Familiarity with Engineering-level mathematics, Calculus, Linear algebra, introduction to Fourier analysis is expected. Prerequisite: Senior standing or permission of instructor.
Credit 3 units.

E62 BME 572 Biological Neural Computation
This course considers the computations performed by the biological nervous system with a particular focus on neural circuits and population-level encoding/decoding. Topics include Hodgkin-Huxley equations; phase-plane analysis; reduction of Hodgkin-Huxley equations; models of neural circuits; plasticity and learning; and pattern recognition and machine learning algorithms for analyzing neural data. Note: Graduate students in psychology or neuroscience who are in the Cognitive, Computational and Systems Neuroscience curriculum pathway may register in Biol 5657 for 3 credits. For non-BME majors, conceptual understanding, and selection/application of right neural data analysis technique are stressed. Hence homework assignments/examinations for the two sections are different, however all students are required to participate in a semester-long independent project as part of the course. Prerequisites: calculus, differential equations, basic probability and linear algebra. Undergraduates need permission of the instructor. Biol 5657 prerequisites: permission from the instructor.
Credit 3 units. EN: TU

E62 BME 5735 Biomedical Engineering Entrepreneurship
Students will learn about entrepreneurship, including IP, business development, and fundraising, through case studies.
Same as E62 BME 4735
Credit 3 units.

E62 BME 574 Quantitative Bioelectricity and Cardiac Excitation
Action potential generation, action potential propagation, source-field relationships in homogeneous and inhomogeneous media, models of cardiac excitation and arrhythmia, quantitative electrocardiography. Prerequisites: differential equations, Laplace transform, electromagnetic field theory (undergraduate level).
Credit 3 units. EN: TU

E62 BME 575 Molecular Basis of Bioelectrical Excitation
Ion channels are the molecular basis of membrane excitability in all cell types, including neuronal, heart and muscle cells. This course presents the structure and the mechanism of function of ion channels at the molecular level. It introduces the basic principles and methods in the ion channel study as well as the structure-function relation of various types of channels. Exemplary channels that have been best studied are discussed to illustrate the current understanding. Prerequisites: knowledge of differential equations, electrical circuits and chemical kinetics.
Credit 3 units. EN: TU

E62 BME 5771 Biomedical Product Development
Advances in science and technology have opened the health care field to innovation now more than any other time in history. Engineers and inventors can make real and rapid improvements to patient treatments, length of hospital stay, procedure time, cost containment, and accessibility to treatment. However, a successful transition from idea to implementation requires careful market analysis and strategy planning. This course will address the steps in this process, including personal and team strength assessment, medical need validation, brainstorming initial solutions, market analysis, solution evaluation, regulatory, patent and intellectual property concerns, manufacturability, risk assessment and mitigation, and global considerations. Students will be expected to review resource material prior to coming to class in order to facilitate active class discussion and team-based application of the material during class; regular attendance will be key to course success. The course will focus on applying product development techniques to several real unmet medical needs; students will thus perform analysis and create reports and presentations for several different product solutions. Peer and faculty evaluations will provide feedback to improve individual technique. In addition, throughout the semester, local biomedical entrepreneurs will visit to share their expertise and experiences. Prerequisites: graduate or professional student standing or permission of the instructor.
Credit 3 units.

E62 BME 5772 Biomedical Business Development
For medical innovators, a successful translation from product to market will require careful strategy and an understanding of the steps needed to form and fund a biotech business, either as a new startup or as an extension of the product line of an existing company. This course will address the steps in this process, including intellectual property concerns, R&D, clinical strategy, regulatory issues, quality management, reimbursement, marketing strategy, sales and distribution, operating plans, and approaches to funding. Prerequisites: graduate or professional student standing or permission of the instructor.
Credit 3 units.

E62 BME 579 Biofabrication & Medical Devices
This course will cover materials design and modern manufacturing methods for biofabricated tissues and medical devices (with a particular emphasis on bioelectronic devices). Topics will include additive manufacturing and their materials requirements along with how these methods have evolved to use biomaterials and cells, such as bioprinting. State-of-the-art in vitro and implantable devices for diagnostic and therapeutic purposes will be discussed with emphasis on how their properties have advanced from developments in materials and manufacturing. Lecture material and assignments will draw from both current market devices and the clinical standard-of-care as well as ongoing research and recent scientific literature. All students will be placed on a waitlist. Registration will be split between undergraduate and graduate students. Prerequisite: E62 BME 523 or equivalent biomaterials introductory course
Same as E62 BME 479
Credit 3 units. EN: TU

E62 BME 5799 Independent Study for Candidates in the Master of Engineering Program
Independent investigation on a topic of special interest. The student and mentor must justify the requested number of units. The MEng program director must approve the requested number of units.
Credit variable, maximum 6 units.

E62 BME 5820 Fundamentals and Applications of Modern Optical Imaging
Analysis, design, and application of modern optical imaging systems, with emphasis on biological imaging. The first part of the course will focus on the physical principles underlying the operation of imaging systems and their mathematical models. Topics include ray optics (speed of light, refractive index, laws of reflection and refraction, plane surfaces, mirrors, lenses, aberrations), wave optics (amplitude and intensity, frequency and wavelength, superposition and interference, interferometry), Fourier optics (space-invariant linear systems, Huygens-Fresnel principle, angular spectrum, Fresnel diffraction, Fraunhofer diffraction, frequency analysis of imaging systems), and light-matter interaction (absorption, scattering, dispersion, fluorescence). The second part of the course will compare modern quantitative imaging technologies, including but not limited to digital

holography, computational imaging, and super-resolution microscopy. Students will evaluate and critique recent optical imaging literature. Prerequisites: ESE 318 and ESE 319 or their equivalents; ESE 330 or Physics 421 or equivalent.
Same as E35 ESE 582
Credit 3 units. EN: TU

E62 BME 589 Biological Imaging Technology
This class develops a fundamental understanding of the physics and mathematical methods that underlie biological imaging and critically examine case studies of seminal biological imaging technology literature. The physics section examines how electromagnetic and acoustic waves interact with tissues and cells, how waves can be used to image the biological structure and function, image formation methods and diffraction limited imaging. The math section examines image decomposition using basis functions (e.g., Fourier transforms), synthesis of measurement data, image analysis for feature extraction, reduction of multidimensional imaging datasets, multivariate regression and statistical image analysis. Original literature on electron, confocal and two photon microscopy, ultrasound, computed tomography, functional and structural magnetic resonance imaging and other emerging imaging technology are critiqued.
Same as E35 ESE 589
Credit 3 units. EN: TU

E62 BME 5901 Integrative Cardiac Electrophysiology
Quantitative electrophysiology of the heart, integrating from the molecular level (ion channels, regulatory pathways, cell signaling) to the cardiac cell (action potential and calcium transient), multicellular tissue (cell-cell communication) and the whole heart. Prerequisite: permission of instructor.
Credit 3 units. EN: BME T, TU

E62 BME 5902 Cellular Neurophysiology
This course will examine the biophysical concepts of synaptic function, with a focus on the mechanisms of neural signal processing at synapses and elementary circuits. The course combines lectures and discussion sessions of primary research papers. Topics include synaptic and dendritic structure, electrical properties of axons and dendrites, synaptic transmission, rapid and long-term forms of synaptic plasticity, information analysis by synapses and basic neuronal circuits, principles of information coding, mechanisms of learning and memory, function of synapses in sensory systems, and models of synaptic disease states such as Parkinson's and Alzheimer's diseases. In addition, a set of lectures will be devoted to modern electrophysiological and imaging techniques as well as modeling approaches to study synapses and neural circuits. Prerequisite: senior or graduate standing.
Credit 3 units. EN: TU

E62 BME 591 Biomedical Optics I: Principles
This course covers the principles of optical photon transport in biological tissue. This course covers the principles and applications of optical photon transport in biological tissue. Topics include a brief introduction to biomedical optics, single-scatterer theories, Monte Carlo modeling of photon transport, convolution for broad-beam responses, radiative transfer equation, diffusion theory and applications, sensing of optical properties and spectroscopy, and photoacoustic imaging principles and applications. Prerequisite: Familiarity with differential equations and partial differential equations.
Credit 3 units. EN: TU

E62 BME 5911 Cardiovascular Biophysics Journal Club
This journal club is intended for beginning graduate students, advanced undergraduates and MSTP students with a background in the quantitative sciences (engineering, physics, math, chemistry, etc.). The subjects covered are inherently multidisciplinary. We review landmark and recent publications in quantitative cardiovascular physiology, mathematical modeling of physiologic systems and related topics such as chaos theory and nonlinear dynamics of biological systems. Familiarity with calculus, differential equations and basic engineering/thermodynamic principles is assumed. Knowledge of anatomy/physiology is optional.
Credit 1 unit.

E62 BME 5913 Molecular Systems Biology: Computation & Measurements for Understanding Cell Physiology and Disease
Systems-level measurements of molecules in cells and tissues harbor the promise of identifying the ways in which tissues develop, maintain, age, and become diseased. This class will introduce the systems-level measurement techniques for capturing molecular information and the mathematical and computational methods for harnessing the information from these measurements to improve our understanding of cell physiology and disease. This is a practical class, which involves implementation of the concepts in MATLAB and will be applied to existing, real data from published journal articles. Molecular topics will include gene expression, microRNA, proteins, post-translational modifications, drugs, and splicing. Computational/mathematical topics covered will include statistical inference, dimensionality reduction techniques, unsupervised and supervised machine learning, and graph-based techniques. Prerequisites: A working knowledge of molecular biology, linear algebra, and statistics is required.
Credit 3 units. EN: TU

E62 BME 592 Biomedical Optics II: Imaging
This course covers optical imaging technologies. Topics include ballistic imaging, optical coherence tomography, Mueller optical coherence tomography, diffuse optical tomography, photoacoustic tomography, and ultrasound-modulated optical tomography. Prerequisites: L24 Math 217; E62 BME 591
Credit 3 units. EN: BME T, TU

E62 BME 594 Ultrasound Imaging
Ultrasound imaging is the most widely used medical imaging modality in the world. This course offers an introduction to the medical ultrasound field. It exposes students to fundamental physical principles of ultrasound, ultrasound imaging, and ultrasound therapy. It will also introduce emerging ultrasound technologies in industry and clinics. Students will learn via lectures, homework, lab exercises, and a final project to gain knowledge, learn the ability to think critically, and develop problem-solving skills.
Same as E62 BME 494
Credit 3 units. EN: TU

E62 BME 595 Drug Delivery Systems: Principles and Applications
Drug delivery is a promising approach for transporting pharmaceutical treatments in the body to safely achieve the desired therapeutic effect, while reducing the undesired side effects. This course will introduce students to the fundamental concepts of drug pharmacokinetics and dynamics, the biological and physiochemical principles drug delivery systems are based on, and the advantages of such delivery systems. Additionally, we will introduce the design and development of advanced drug delivery platforms such as nano-carriers, cell/gene delivery systems, drug-polymer conjugates and their relevant clinical applications. Finally, we will be having guest speakers from the industry, the university, as well as the office of technology management for Interdisciplinary Innovation & Entrepreneurship.

Credit 3 units.

E62 BME 601C Research Rotation for BME Doctoral Students
Credit 3 units.

PhD and Combined MD/PhD in Biomedical Engineering

The department offers programs that lead to the Doctor of Philosophy (PhD) in Biomedical Engineering as well as combined MD/PhD degrees. The latter degrees are conferred jointly with the School of Medicine.

The doctoral degree requires a minimum of 72 credits beyond the bachelor's level, with a minimum of 36 being course credits (including the core curriculum) and a minimum of 24 credits of doctoral dissertation research.

The core curriculum that must be satisfied by all PhD students consists of the following:

- One graduate-level course in life science from an approved list
- One graduate-level course in mathematics from an approved list
- One graduate-level course in computer science from an approved list or exemption by proficiency
- Four BME courses from an approved list

Please visit the Biomedical Engineering (BME) website (https://bme.wustl.edu/graduate/phd/Pages/default.aspx) for a comprehensive list of the approved courses.

Up to 9 credits of BME 601C Research Rotation for BME Doctoral Students and/or BME 501C BME Doctoral Seminar Series may be counted toward the 36 credits of graduate courses required for the PhD, so a total of 27 additional credits (usually nine courses, including the core curriculum) are required for the PhD. Up to two 400-level courses may be counted toward the nine courses required for the PhD. Graduate courses may be transferred in (up to 24 credits) but must be evaluated and approved by the Director of Doctoral Studies. The evaluation and approval may occur at any time, but course transfer does not become official until after one year in residence at Washington University.

Students seeking the **PhD in Biomedical Engineering** enroll in two to three courses each semester and participate in one or two laboratory rotations during the first year. Before the end of their first 10 months of enrollment in the program, students take their oral qualifying exam, which consists of a presentation of their research done to date in the mentor's laboratory followed by an oral exam addressing any issues directly related to their rotation report or their oral presentation. Upon successfully passing the qualifying examination, they advance to candidacy and complete the balance of their requirements. During the second and third years, students complete their remaining courses, participate in one semester of a mentored teaching experience, and begin their thesis research. By the end of the third year, students must complete their thesis proposal. Students must also complete one accepted and one submitted first-author publication and complete a dissertation.

Students pursuing the combined **MD/PhD in Biomedical Engineering** must complete the degree requirements in both schools. MD/PhD students typically complete the first two years of the medical school preclinical curriculum while also performing one or more research rotations, then the remaining requirements for the doctoral degree, and finally the clinical training years of the medical degree. The department generally gives graduate course credits for some of the medical school courses toward the fulfillment of course requirements for the PhD degree. This is arranged on an individual basis between the student, their academic advisor and the Director of Doctoral Studies.

Master of Science (MS) in Biomedical Engineering

The core curriculum that must be satisfied by all graduate MS students consists of the following:

- One graduate-level course in life sciences
- One graduate-level course in mathematics or computer science
- Three BME courses from the approved course list

Please visit the Policies and Regulations Guide located on the Biomedical Engineering (BME) website (http://bme.wustl.edu/graduate/ms/Pages/default.aspx) for a comprehensive list of the core and approved courses.

Candidates for the MS must accumulate a total of 30 graduate course credits beyond the bachelor's degree. Only 6 of these 30 credits may be transferred from another university. There are two options to obtain the degree: thesis and non-thesis.

Thesis Option

For this option, a minimum of 24 graduate course credits is required, with the balance being thesis research. The courses must fulfill the core curriculum requirements; courses can be found in the Policies and Regulations Guide on the BME website (http://bme.wustl.edu/graduate/ms/Pages/default.aspx).

The remainder of the course work is generally driven by the student's research interest. Upon completion of the thesis, the candidate must pass an oral defense conducted by their thesis committee. This will consist of a public presentation followed by questions from the committee. Candidates must have a cumulative grade-point average of 2.7 or better to receive the degree.

Non-Thesis Option

Candidates must accumulate a total of 30 graduate credits, have a cumulative GPA of 2.7 or better, and satisfy the core curriculum requirements; courses can be found in the Policies and Regulations Guide on the BME website (http://bme.wustl.edu/graduate/ms/Pages/default.aspx). The balance of the course credits should be selected with a view toward coherence reflecting a specialization in a research area.

Graduate-level courses given by other departments and schools may be substituted for courses in the approved list with the permission of the Director of Master's Studies. The full list of approved courses can be found in the Policies and Regulations Guide on the BME website (http://bme.wustl.edu/graduate/ms/Pages/default.aspx).

Computational & Data Sciences (Interdisciplinary PhD)

The Division of Computational & Data Sciences (DCDS) at Washington University in St. Louis trains students interested in problems from across a range of disciplines that share a common reliance on data and computing.

The introduction of now-standard tools from statistical analysis and hypothesis testing transformed the practice of natural and social science in the mid-20th century. Emerging tools from computational and data science have the potential to bring about an even larger transformation of scientific practice, especially in the social sciences. The questions raised by data generated by and about human behavior are engaging and profound. However, many if not most of these questions can only be tackled using a multidisciplinary approach that combines a deep knowledge of the capabilities and operation of data science techniques with the domain expertise needed to apply them effectively to the problems under consideration.

Doctoral students in Computational & Data Sciences receive strong methodological training in modern computational and statistical methods, and they also acquire expertise in a particular social science application area.

The program is inherently interdisciplinary and brings together leading experts from across the university who are using data to solve some of the greatest challenges that our world faces today. Faculty include both data and computing experts as well as domain experts from different application areas.

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Degree Requirements

PhD in Computational & Data Sciences

Upon joining the PhD program, each student is assigned an initial advisor from the DCDS faculty. This advisor meets with the student to assess their background and to advise them on course selection.

All students complete a common core curriculum as well as a domain depth requirement in a social science area. The focus of the first year is on acquiring a common set of tools and an understanding of the ranges and types of problems students may work on as they progress through the program. The entire incoming cohort takes a unique two-semester seminar sequence solely for DCDS students, which includes both general topics and a series of data-driven dives into the types of research questions that may be encountered in each of the domain areas.

In addition, students will be exposed to research in different areas through “rotations” that start in the fall semester of their first year. By the end of the summer following their first year, each student will put together an advisory committee of at least two DCDS faculty members (preferably from different tracks) and identify the specific track in which they plan to do research and pursue their degree.

Curriculum

Required Core Courses (24 credit units)

- **CSE 502N: Data Structures and Algorithms (3 credits):** This is an existing fundamental course in algorithms and data structures, including significant implementation in an object-oriented programming language (currently Java). We expect that many students will already have this background; the course is intended as a pathway for students with very little computational training.
- **Quantitative Methods I and II (6 credits):** This two-semester sequence covers essential probability and statistics, including hypothesis testing, inference and experimental methodology using a modern statistical computing language like R. The introductory courses offered by the departments of Psychological & Brain Sciences (Psych 5066) and Political Science (Pol Sci 581) will count for Quantitative Methods I credit. Their follow-up courses (Psych 5067 and Pol Sci 582) will count for Quantitative Methods II credit.
- **DCDS 510: Data Wrangling (3 credits):** We are in a new era in terms of the volume and modalities of data generated by efforts to measure human behavior. This will be a new cross-listed course that introduces students to the tools and techniques used to collect, maintain and process large-scale data sets of the kind generated in the course of studying people and social systems.
- **CSE 417T and CSE 517A: Machine Learning I and II (6 credits):** This is a two-semester sequence in machine learning. Together, the two courses cover the fundamental principles of supervised learning, including generalization, overfitting, regularization, cross-validation, model selection, and core machine learning techniques and algorithms, including linear models like logistic regression, gradient descent, tree-based and ensemble methods, kernel methods, deep neural networks and topics in unsupervised learning.
- **Computational and Data Sciences Seminar Series (6 credits):** This two-semester seminar sequence is cross-listed across participating departments and team-taught by participating faculty.
  - DCDS 499: Introduction to Graduate Research in Computational & Data Sciences will be structured around topics and ideas that do not need detailed specific-content background. The topics covered will include ethics, the nature of research, robustness and reproducibility of research, and presentations from across the different areas of interest to give students an understanding of research in human and social data analytics across the university.
  - DCDS 500: Computational and Data Sciences Research Exploration will be structured as a series of deep dives into data-driven approaches in each of the domain areas, including a module on computational methodologies. In each of these modules, the students will either be given a

specific dataset to investigate or a specific hands-on task to complete (e.g., developing a visualization, assessing how easy a computational tool is for social scientists to use). Students will work in teams on these projects.

Domain Depth Tracks

Students will choose one of four focus tracks: Political Science, Psychological & Brain Sciences, Social Work & Public Health, or Computational Methodologies. Depending on the track, students must complete the following domain depth requirements:

1. **Political Science track:** Students must complete three substantive courses in one subfield (e.g., American politics, comparative politics, international relations) from a specified list for each subfield as well as a research design course (Pol Sci 540).
2. **Psychological & Brain Sciences track:** Students must complete three substantive courses in one subfield (e.g., brain, behavior and cognition, clinical science, social/personality, development and aging). With permission, students may substitute the Psychological & Brain Sciences Research Methods Course (Psych 5011) for one of the substantive courses, depending on their background in psychological science.
3. **Social Work & Public Health track:** Students must complete a three-course core doctoral seminar series, including conceptual foundations of social science, advanced research methods, and a theory seminar, either in public health or social work. Students will also be required to take an advanced substantive course from an approved list in their area of interest.
4. **Computational Methodologies track:** Students must take CSE 541T Advanced Algorithms and either CSE 412A Introduction to Artificial Intelligence or CSE 515T Bayesian Methods in Machine Learning. In addition, students must take two substantive courses in their area of interest (i.e., political science, psychological & brain sciences, or social work & public health) from among the courses acceptable for students in that track as noted above.

Sample Curriculum

A typical progression of courses is described below, with separate examples for students who enter with and without more extensive computational backgrounds.

Students Without Much Computer Science Background

Course	Fall Units	Spring Units
First Year		
Data Structures and Algorithms (CSE 502N)	3	—
Quantitative Methods I	3	—
CDS Seminar I	3	—
Introduction to Machine Learning (CSE 417T)	—	3
Data Wrangling	—	3
CDS Seminar II	—	3
	9	**9**
Second Year		
Quantitative Methods II	3	—
Domain course	3	3
Domain course or elective	3	3
Machine Learning (CSE 517A)	—	3
	9	**9**

Students With More Computer Science Background

Course	Fall Units	Spring Units
First Year		
Introduction to Machine Learning (CSE 417T) or domain course	3	—
Quantitative Methods I	3	—
CDS Seminar I	3	—
Introduction to Machine Learning (CSE 417T) or domain course	—	3
Data Wrangling	—	3
CDS Seminar II	—	3
	9	**9**
Second Year		
Quantitative Methods II	3	—
Domain course	3	3
Domain course or elective	3	3
Machine Learning (CSE 517A)	—	3
	9	**9**

Further Requirements

Additional requirements for this program are as follows:

- A minimum of 72 credit units beyond the bachelor's level, with a minimum of 37 being course credits (including the core curriculum)
- A minimum of 24 credit units of doctoral dissertation research
- Students must maintain a cumulative average grade of B (3.0 grade-point average) for all 72 credit units.
- Required courses must be completed with no more than one grade below a B-.
- Up to 24 graduate credit units may be transferred with the approval of the Graduate Studies Committee, which is chaired by the director of graduate studies.

In addition to fulfilling the course and research credit requirements, students must do the following:

- Complete at least two three-month-long research rotations.
- Pass a qualifying exam.
- Successfully defend a thesis proposal.
- Present and successfully defend a dissertation.
- Complete a teaching requirement consisting of two semesters of mentored teaching experience.

Computer Science & Engineering

During the past two decades, society has experienced unprecedented growth in digital technology. This revolution continues to redefine our way of life, our culture and our economy. Computer science and engineering education plays an irreplaceable role in this trend by preparing future technology leaders and innovators. It opens our minds to new horizons, unlocks doors to a broad range of career paths, accelerates professional advancement, and exposes us to ideas that are advancing the frontiers of science and technology beyond the field of computing. Alumni and students continually remind us that pursuing a degree in the Department of Computer Science & Engineering is an experience rarely matched elsewhere.

Master's Programs

The Department of Computer Science & Engineering offers four master's degrees: **Master of Science in Computer Science, Master of Science in Computer Engineering, Master of Science in Cybersecurity Engineering,** and **Master of Engineering in Computer Science and Engineering.** We accept both full-time and part-time students, offering class schedules that are flexible enough for part-time students but that provide enough classes for students to attend full-time. Obtaining a master's degree from the Department of Computer Science & Engineering can be done as a pure course option (MS in Computer Science and MS in Computer Engineering degrees only), or it can incorporate a specialized research experience. Master's research is a great way for our students to easily transition into future doctoral studies. Graduates of our program are also prepared to enter the industry, with many accepting positions at companies like Boeing, Google and Microsoft. Applicants to our master's programs are expected to have completed an undergraduate degree. A major or minor in computer science or computer engineering is helpful, but it is not required. Background requirements are listed within each degree program, along with options for meeting them.

PhD Programs

The Department of Computer Science & Engineering offers **PhD programs in Computer Science and in Computer Engineering.** Computer science research encompasses the fundamentals of software and algorithm design, machine learning and bioinformatics, visual and cyber-physical computing, and human-computer interaction. Computer engineering focuses on the interaction of software and hardware in the design of computing systems and networks. Our research groups have extensive interdisciplinary ties across the university, with collaborations in medicine, science, the humanities and social work. Recent graduates have accepted research and teaching faculty positions as well as research and engineering positions in leading technology companies.

Both PhD programs require a combination of courses, research and teaching. The required courses are often completed early in the program, since students are integrated into research groups during their first year and the program's emphasis is on creative research. The program has milestones that involve both written and oral components, and these provide structure for the five- to six-year degree. The program considers applicants with either bachelor's or master's degrees and has had successful applicants in the past whose backgrounds were outside of the field of computer science.

Phone:	314-935-6132
Email:	admissions@cse.wustl.edu
Website:	https://cse.wustl.edu/academics/graduate/index.html

Faculty

Chair

Roch Guérin (https://engineering.wustl.edu/faculty/Roch-Guerin.html)
Harold B. and Adelaide G. Welge Professor of Computer Science
PhD, California Institute of Technology
Computer networks and communication systems

Professors

Sanjoy Baruah (https://engineering.wustl.edu/faculty/Sanjoy-Baruah.html)
PhD, University of Texas at Austin
Real-time and safety-critical system design, cyber-physical systems, scheduling theory, resource allocation and sharing in distributed computing environments

Aaron Bobick (https://engineering.wustl.edu/faculty/Aaron-Bobick.html)
James M. McKelvey Professor and Dean
PhD, Massachusetts Institute of Technology
Computer vision, graphics, human-robot collaboration

Michael R. Brent (https://engineering.wustl.edu/faculty/Michael-Brent.html)
Henry Edwin Sever Professor of Engineering
PhD, Massachusetts Institute of Technology
Systems biology, computational and experimental genomics, mathematical modeling, algorithms for computational biology, bioinformatics

Jeremy Buhler (https://engineering.wustl.edu/faculty/Jeremy-Buhler.html)
PhD, Washington University
Computational biology, genomics, algorithms for comparing and annotating large biosequences

Roger D. Chamberlain (https://engineering.wustl.edu/faculty/Roger-Chamberlain.html)
DSc, Washington University
Computer engineering, parallel computation, computer architecture, multiprocessor systems

Yixin Chen (https://engineering.wustl.edu/faculty/Yixin-Chen.html)
PhD, University of Illinois at Urbana-Champaign
Mathematical optimization, artificial intelligence, planning and scheduling, data mining, learning data warehousing, operations research, data security

Patrick Crowley (https://engineering.wustl.edu/faculty/Patrick-Crowley.html)
PhD, University of Washington
Computer and network systems, network security

Ron K. Cytron (https://engineering.wustl.edu/faculty/Ron-Cytron.html)
PhD, University of Illinois at Urbana-Champaign
Programming languages, middleware, real-time systems

Christopher D. Gill (https://engineering.wustl.edu/faculty/Christopher-Gill.html)
DSc, Washington University
Parallel and distributed real-time embedded systems, cyber-physical systems, concurrency platforms and middleware, formal models and analysis of concurrency and timing

Raj Jain (https://engineering.wustl.edu/faculty/Raj-Jain.html)
Barbara J. & Jerome R. Cox Jr. Professor of Computer Science
PhD, Harvard University
Network security, blockchains, medical systems security, industrial systems security, wireless networks, unmanned aircraft systems, internet of things, telecommunications networks, traffic management

Tao Ju (https://engineering.wustl.edu/faculty/Tao-Ju.html)
PhD, Rice University
Computer graphics, visualization, mesh processing, medical imaging and modeling

Chenyang Lu (https://engineering.wustl.edu/faculty/Chenyang-Lu.html)
Fullgraf Professor in the Department of Computer Science & Engineering
PhD, University of Virginia
Internet of things, real-time, embedded, and cyber-physical systems, cloud and edge computing, wireless sensor networks

Neal Patwari (https://engineering.wustl.edu/faculty/Neal-Patwari.html)
PhD, University of Michigan
Application of statistical signal processing to wireless networks, and radio frequency signals

Weixiong Zhang
PhD, University of California, Los Angeles
Computational biology, genomics, machine learning and data mining, and combinatorial optimization

Associate Professors

Kunal Agrawal (https://engineering.wustl.edu/faculty/Kunal-Agrawal.html)
PhD, Massachusetts Institute of Technology
Parallel computing, cyber-physical systems and sensing, theoretical computer science

Roman Garnett (https://engineering.wustl.edu/faculty/Roman-Garnett.html)
PhD, University of Oxford
Active learning (especially with atypical objectives), Bayesian optimization, and Bayesian nonparametric analysis

Brendan Juba (https://engineering.wustl.edu/faculty/Brendan-Juba.html)
PhD, Massachusetts Institute of Technology
Theoretical approaches to artificial intelligence founded on computational complexity theory and theoretical computer science more broadly construed

Caitlin Kelleher (https://engineering.wustl.edu/faculty/Caitlin-Kelleher.html)
Hugo F. & Ina Champ Urbauer Career Development Associate Professor

PhD, Carnegie Mellon University
Human-computer interaction, programming environments, and learning environments

I-Ting Angelina Lee
PhD, Massachusetts Institute of Technology
Designing linguistics for parallel programming, developing runtime system support for multi-threaded software, and building novel mechanisms in operating systems and hardware to efficiently support parallel abstractions

William D. Richard (https://engineering.wustl.edu/faculty/William-Richard.html)
PhD, University of Missouri-Rolla
Ultrasonic imaging, medical instrumentation, computer engineering

Yevgeniy Vorobeychik (https://engineering.wustl.edu/faculty/Yevgeniy-Vorobeychik.html)
PhD, University of Michigan
Artificial intelligence, machine learning, computational economics, security and privacy, multi-agent systems

William Yeoh (https://engineering.wustl.edu/faculty/William-Yeoh.html)
PhD, University of Southern California
Artificial intelligence, multi-agent systems, distributed constraint optimization, planning and scheduling

Assistant Professors

Ayan Chakrabarti
PhD, Harvard University
Computer vision computational photography, machine learning

Chien-Ju Ho (https://engineering.wustl.edu/faculty/Chien-Ju-Ho.html)
PhD, University of California, Los Angeles
Design and analysis of human-in-the-loop systems, with techniques from machine learning, algorithmic economics, and online behavioral social science

Ulugbek Kamilov (https://engineering.wustl.edu/faculty/Ulugbek-Kamilov.html)
PhD, École Polytechnique Fédérale de Lausanne, Switzerland
Computational imaging, image and signal processing, machine learning and optimization

Alvitta Ottley (https://engineering.wustl.edu/faculty/Alvitta-Ottley.html)
PhD, Tufts University
Designing personalized and adaptive visualization systems, including information visualization, human-computer interaction, visual analytics, individual differences, personality, user modeling and adaptive interfaces

Netanel Raviv (https://engineering.wustl.edu/faculty/Netanel-Raviv.html)
PhD, Technion, Haifa, Israel
Mathematical tools for computation, privacy and machine learning

Ning Zhang (https://engineering.wustl.edu/faculty/Ning-Zhang.html)
PhD, Virginia Polytechnic Institute and State University
System security, software security

Teaching Professor

Bill Siever
PhD, Missouri University of Science and Technology
Computer architecture, organization, and embedded systems

Todd Sproull (https://engineering.wustl.edu/faculty/Todd-Sproull.html)
PhD, Washington University
Computer networking and mobile application development

Professor of the Practice

Dennis Cosgrove (https://engineering.wustl.edu/faculty/Dennis-Cosgrove.html)
BS, University of Virginia
Programming environments and parallel programming

Senior Lecturers

Steve Cole
PhD, Washington University in St. Louis
Parallel computing, accelerating streaming applications on GPUs

Marion Neumann (https://engineering.wustl.edu/faculty/Marion-Neumann.html)
PhD, University of Bonn, Germany
Machine learning with graphs; solving problems in agriculture and robotics

Jonathan Shidal (https://engineering.wustl.edu/faculty/Jonathan-Shidal.html)
PhD, Washington University
Computer architecture and memory management

Douglas Shook (https://engineering.wustl.edu/faculty/Doug-Shook.html)
MS, Washington University
Imaging sensor design, compiler design and optimization

Lecturers

Hila Ben Abraham
PhD, Washington University in St. Louis
Parallel computing, accelerating streaming applications on GPUs, computer and network security, and malware analysis

Brian Garnett (https://engineering.wustl.edu/faculty/Brian-Garnett.html)
PhD, Rutgers University
Discrete mathematics and probability, generally motivated by theoretical computer science

James Orr (https://engineering.wustl.edu/faculty/James-Orr.html)
PhD, Washington University
Real-time systems theory and implementation, cyber-physical systems, and operating systems

Senior Professor

Jonathan S. Turner (https://engineering.wustl.edu/faculty/Jon-Turner.html)
PhD, Northwestern University
Design and analysis of internet routers and switching systems, networking and communications, algorithms

Senior Faculty Emeritus

Jerome R. Cox Jr.
ScD, Massachusetts Institute of Technology
Computer system design, computer networking, biomedical computing

Professors Emeriti

Takayuki D. Kimura
PhD, University of Pennsylvania
Communication and computation, visual programming

Seymour V. Pollack
MS, Brooklyn Polytechnic Institute
Intellectual property, information systems

Degree Requirements

Please visit to the following pages for information about computer science and engineering graduate programs:

- PhD in Computer Science or Computer Engineering (p. 50)
- Master of Science (MS) in Computer Science (p. 51)
- Master of Science (MS) in Computer Engineering (p. 51)
- Master of Science (MS) in Cybersecurity Engineering (p. 52)
- Master of Engineering (MEng) in Computer Science and Engineering (p. 52)
- Certificate in Data Mining and Machine Learning (p. 53)
- Certificate in Cybersecurity Engineering (p. 54)

Courses

Visit online course listings to view semester offerings for E81 CSE (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E81&crslvl=5:8).

E81 CSE 500 Independent Study
Proposal form can be located at https://cse.wustl.edu/undergraduate/PublishingImages/Pages/undergraduate-research/Independent%20Study%20Form%20400.pdf
Credit variable, maximum 3 units.

E81 CSE 501N Introduction to Computer Science
An introduction to software concepts and implementation, emphasizing problem solving through abstraction and decomposition. Introduces processes and algorithms, procedural abstraction, data abstraction, encapsulation, and object-oriented programming. Recursion, iteration, and simple data structures are covered. Concepts and skills are mastered through programming projects, many of which employ graphics to enhance conceptual understanding. Java, an object-oriented programming language, is the vehicle of exploration. Active-learning sessions are conducted in a studio setting in which students interact with each other and the professor to solve problems collaboratively. Prerequisites: Comfort with algebra and geometry at the high school level is assumed. Patience, good planning, and organization will promote success. This course assumes no prior experience with programming.
Same as E81 CSE 131
Credit 3 units. BU: SCI EN: TU

E81 CSE 502N Data Structures and Algorithms
Study of fundamental algorithms, data structures, and their effective use in a variety of applications. Emphasizes importance of data structure choice and implementation for obtaining the most efficient algorithm for solving a given problem. A key component of this course is worst-case asymptotic analysis, which provides a quick and simple method for determining the scalability and effectiveness of an algorithm. Online textbook purchase required. Prerequisite: CSE 131/501N, and fluency with summations, derivatives, and proofs by induction.
Same as E81 CSE 247
Credit 3 units. EN: TU

E81 CSE 503S Rapid Prototype Development and Creative Programming
This course uses web development as a vehicle for developing skills in rapid prototyping. Students acquire the skills to build a Linux web server in Apache, to write a website from scratch in PHP, to run an SQL database, to perform scripting in Python, to employ various web frameworks, and to develop modern web applications in client-side and server-side JavaScript. The course culminates with a creative project in which students are able to synthesize the course material into a project of their own interest. The course implements an interactive studio format: after the formal presentation of a topic, students develop a related project under the supervision of the instructor. Prerequisite: CSE 131.
Same as E81 CSE 330S
Credit 3 units. EN: BME T, TU

E81 CSE 504N Object-Oriented Software Development Laboratory
Intensive focus on practical aspects of designing, implementing and debugging software, using object-oriented, procedural, and generic programming techniques. The course emphasizes familiarity and proficiency with a wide range of C++ language features through hands-on practice completing studio exercises and lab assignments, supplemented with readings and summary presentations for each session. Prerequisites: CSE 131 and CSE 247
Same as E81 CSE 332S
Credit 3 units. EN: BME T, TU

E81 CSE 505N Introduction to Digital Logic and Computer Design
Introduction to design methods for digital logic and fundamentals of computer architecture. Boolean algebra and logic minimization techniques; sources of delay in combinational circuits and effect on circuit performance; survey of common combinational circuit components; sequential circuit design and analysis; timing analysis of sequential circuits; use of computer-aided design tools for digital logic design (schematic capture, hardware description languages, simulation); design of simple processors and memory subsystems; program execution in simple processors; basic techniques for enhancing processor performance; configurable logic devices. Prerequisite: CSE 131.
Same as E81 CSE 260M
Credit 3 units.

E81 CSE 513T Theory of Artificial Intelligence and Machine Learning
Mathematical foundations for Artificial Intelligence and Machine Learning. An introduction to the PAC-Semantics ("Probably Approximately Correct") as a common semantics for knowledge obtained from learning and declarative sources, and the computational problems underlying the acquisition and processing of such knowledge. We emphasize the design and analysis of efficient algorithms for these problems, and examine for which representations these problems are known or believed to be tractable. Prerequisite: CSE 347.
Credit 3 units. EN: TU

E81 CSE 514A Data Mining
With the vast advancements in science and technology, the acquisition of large quantities of data is routinely performed in many fields. Examples of large data include various types of data on the internet, high-throughput sequencing data in biology and medicine, extraterrestrial data from telescopes in astronomy, and images from surveillance cameras in security settings. Analyzing a large amount of data through data mining has become an effective means of extracting knowledge from data. This course introduces the basic concepts and methods of data mining and provides hands-on experience for processing, analyzing and modeling structured and unstructured data. Homework problems, exams, and programming assignments will be administrated throughout the course to enhance students' learning. Prerequisites: CSE 247, ESE 326 (or Math 3200 or Engr 328), and Math 233.
Credit 3 units. EN: BME T, TU

E81 CSE 515T Bayesian Methods in Machine Learning
This course will cover machine learning from a Bayesian probabilistic perspective. Bayesian probability allows us to model and reason about all types of uncertainty. The result is a powerful, consistent framework for approaching many problems that arise in machine learning, including parameter estimation, model comparison, and decision making. We will begin with a high-level introduction to Bayesian inference and then proceed to cover more advanced topics. These will include inference techniques (e.g., exact, MAP, sampling methods, the Laplace approximation), Bayesian decision theory, Bayesian model comparison, Bayesian nonparametrics, and Bayesian optimization. Prerequisites: CSE 417T and ESE 326.
Credit 3 units. EN: BME T, TU

E81 CSE 516A Multi-Agent Systems
This course introduces the fundamental techniques and concepts needed to study multi-agent systems, in which multiple autonomous entities with different information sets and goals interact. We will study algorithmic, mathematical, and game-theoretic foundations, and how these foundations can help us understand and design systems ranging from robot teams to online markets to social computing platforms. Topics covered may include game theory, distributed optimization, multi-agent learning and decision-making, preference elicitation and aggregation, mechanism design, and incentives in social computing systems. Prerequisites: CSE 347 (may be taken concurrently), ESE 326 (or Math 3200), and Math 233 or equivalents. Some prior exposure to artificial intelligence, machine learning, game theory, and microeconomics may be helpful, but is not required.
Credit 3 units. EN: BME T, TU

E81 CSE 517A Machine Learning
This course is the second course of a two-course sequence on machine learning (CSE 417T and CSE 517A). It assumes a fundamental understanding of machine learning foundations (both theoretical and practical) and introduces probabilistic machine learning approaches in depth as well as advanced topics at the frontier of the field. Topics to be covered include discriminative and generative probabilistic models, kernel methods (e.g., support vector machines, Gaussian processes), neural networks (deep learning), unsupervised learning techniques, and practical machine learning (e.g., feature engineering, dimensionality reduction, model comparison). Prerequisites: Math 233, CSE 247, ESE 326 or Math 3211, Math 309, and CSE 417T or ESE 417.
Credit 3 units. EN: TU

E81 CSE 518A Human-in-the-Loop Computation
This course is an exploration of the opportunities and challenges of human-in-the-loop computation, an emerging field that examines how humans and computers can work together to solve problems neither can yet solve alone. We will explore ways in which techniques from machine learning, game theory, optimization, online behavioral social science, and human-computer interactions can be used to model and analyze human-in-the-loop systems such as crowdsourcing markets, prediction markets, and user-generated content platforms. We will also look into recent developments in the interactions between humans and AIs, such as learning with the presence of strategic behavior and ethical issues in AI systems. Prerequisites: CSE 247, ESE 326, Math 233, and Math 309.
Credit 3 units. EN: BME T, TU

E81 CSE 519T Advanced Machine Learning
This course provides a close look at advanced machine learning algorithms, including their theoretical guarantees (computational learning theory) and tricks to make them work in practice. In addition, this course focuses on more specialized learning settings, including unsupervised learning, semi-supervised learning, domain adaptation, multi-task learning, structured prediction, metric learning, and learning of data representations. Learning approaches may include graphical models, non-parametric Bayesian statistics, and technical topics such as sampling, approximate inference, and non-linear function optimization. Mathematical maturity and general familiarity with machine learning are required. Prerequisites: CSE 517A.
Credit 3 units. EN: TU

E81 CSE 520S Real-Time Systems
This course covers software systems and network technologies for real-time applications such as automobiles, avionics, industrial automation, and the Internet of Things. Topics include real-time scheduling, real-time operating systems and middleware, quality of service, industrial networks, and real-time cloud computing. Prerequisite: CSE 361S.
Credit 3 units. EN: BME T, TU

E81 CSE 521S Wireless Sensor Networks
Dense collections of smart sensors networked to form self-configuring pervasive computing systems provide a basis for a new computing paradigm that challenges many classical approaches to distributed computing. Naming, wireless networking protocols, data management, and approaches to dependability, real-time, security, and middleware services all fundamentally change when confronted with this new environment. Embedded sensor networks and pervasive computing are among the most exciting research areas with many open research questions. This course will study a large number of research papers that deal with various aspects of wireless sensor networks. Students will perform a project on a real wireless sensor network comprised of tiny devices, each consisting of sensors, a radio transceiver, and a microcontroller. Prerequisite: CSE 361S.
Credit 3 units. EN: BME T, TU

E81 CSE 522S Advanced Operating Systems
This course offers an in-depth hands-on exploration of advanced uses of key OS abstractions, mechanisms and policies, with an increasing focus on understanding and evaluating their behaviors and interactions. Readings, lecture material, studio exercises, and a semester-long project chosen by students are closely integrated in an active-learning environment in which students gain experience and proficiency writing, tracing, and evaluating user-space and kernel-space code. Topics include how memory, processes and threads, virtual file systems, and other mechanisms can be used by hypervisors, containers, and other advanced OS abstractions, as well as forensic techniques for examining and managing system behavior. Prerequisite: CSE 422S.
Credit 3 units. EN: BME T, TU

E81 CSE 523S Systems Security
This course examines the intersection between computer design and information security. While performance and efficiency in digital systems have improved markedly in recent decades, computer security has worsened overall in this time frame. To understand why, we will explore the role that design choices play in the security characteristics of modern computer and network systems. Students will use and write software to illustrate mastery of the material. Projects will include identifying security vulnerabilities, exploiting vulnerabilities, and detecting and defending against exploits. Prerequisite: CSE 361S.
Credit 3 units. EN: BME T, TU

E81 CSE 527A Natural Language Processing
Natural language processing (NLP) is an important part of artificial intelligence (AI), endowing computers with the ability to process human language. NLP techniques are used in applications such as question answering, automatic language translation, and extracting structured information from text. This course will introduce fundamental ideas and recent research trends in NLP. Students will gain theoretical and

practical experience with various NLP techniques (e.g., deep learning) and applications. Pre-reqs: basic linear algebra, basic probability and statistics, basic machine learning (CSE 417T or ESE 417 or instructor consent) and Python programming.
Credit 3 units. EN: TU

E81 CSE 532S Advanced Multiparadigm Software Development
Intensive focus on advanced design and implementation of concurrent and distributed system software in C++. Topics covered include concurrency and synchronization features and software architecture patterns. Prerequisites: CSE 332S or graduate standing and strong familiarity with C++; and CSE 422S.
Credit 3 units. EN: BME T, TU

E81 CSE 533T Coding and Information Theory for Data Science
Coding/information theory emerged in mid 20th century as a mathematical theory of communication with noise. In latter decades it has developed to a vast topic encompassing most aspects of handling large datasets. The course will begin by surveying the classical mathematical theory and its basic applications in communication, and continue to contemporary applications in storage, computation, privacy, machine learning, and emerging technologies such as networks, blockchains, and DNA storage. The course is self-contained, but prior knowledge in algebra (e.g., Math 309, ESE 318), discrete math (e.g., CSE 240, Math 310), and probability (e.g., Math 2200, ESE 326), as well as some mathematical maturity, is assumed. There will be four to five homework assignments, one in-person midterm, and a final reading assignment.
Credit 3 units. EN: BME T, TU

E81 CSE 534A Large-Scale Optimization for Data Science
Large-scale optimization is an essential component of modern data science, artificial intelligence, and machine learning. This graduate-level course rigorously introduces optimization methods that are suitable for large-scale problems arising in these areas. Students will learn several algorithms suitable for both smooth and nonsmooth optimization, including gradient methods, proximal methods, mirror descent, Nesterov's acceleration, ADMM, quasi-Newton methods, stochastic optimization, variance reduction, and distributed optimization. Throughout the course, we will discuss the efficacy of these methods in concrete data science problems, under appropriate statistical models. Students will be required to program in Python or MATLAB. Prerequisites: CSE 247, Math 309, (Math 3200 or ESE 326), ESE 415.
Same as E35 ESE 513
Credit 3 units. EN: TU

E81 CSE 537T Trustworthy Autonomy
Cyber-physical systems are becoming increasingly capable. These are systems consisting of digital and physical components. They are deployed to increase autonomy in critical settings where failure is costly, such as driving, aviation, medicine, and manufacturing. This course covers several approaches for assuring that such systems meet their specifications. We will discuss: (1) how to mathematically model these systems and their specifications, (2) how to formally verify and synthesize models which meet their specifications, and (3) how to address the challenges resulting from incorporating machine-learned components, such as neural networks, as perception and control components in these systems. Prerequisites: CSE240 and CSE247, or approval of instructor. Preferred prerequisites: Math 217, CSE 347, CSE 417T or ESE 417
Credit 3 units.

E81 CSE 538T Modeling and Performance Evaluation of Computer Systems
Modern computing systems consist of multiple interconnected components that all influence performance. The focus of this course is on developing modeling tools aimed at understanding how to design and provision such systems to meet certain performance or efficiency targets and the trade-offs involved. The course covers Markov chains and their applications to simple queues, and it proceeds to explore more complex systems, including server farms and how to optimize their performance through scheduling and task assignment policies. The course includes a brief review of the necessary probability and mathematical concepts. Prerequisite: ESE 326.
Credit 3 units. EN: BME T, TU

E81 CSE 539S Concepts in Multicore Computing
Nowadays, the vast majority of computer systems are built using multicore processor chips. This fundamental shift in hardware design impacts all areas of computer science - one must write parallel programs in order to unlock the computational power provided by modern hardware. The goal of this course is to study concepts in multicore computing. We will examine the implications of the multicore hardware design, discuss challenges in writing high performance software, and study emerging technologies relevant to developing software for multicore systems. Topics include memory hierarchy, cache coherence protocol, memory models, scheduling, high-level parallel language models, concurrent programming (synchronization and concurrent data structures), algorithms for debugging parallel software, and performance analysis. Prerequisites: CSE 247 and CSE 361S.
Credit 3 units. EN: BME T, TU

E81 CSE 541T Advanced Algorithms
Provides a broad coverage of fundamental algorithm design techniques, with a focus on developing efficient algorithms for solving combinatorial and optimization problems. The topics covered include the review of greedy algorithms, dynamic programming, NP-completeness, approximation algorithms, the use of linear and convex programming for approximation, and online algorithms. Throughout this course, there is an emphasis on correctness proofs and the ability to apply the techniques taught to design efficient algorithms for problems from a wide variety of application areas. Prerequisite: CSE 347.
Credit 3 units. EN: BME T, TU

E81 CSE 543S Advanced Secure Software Engineering
The aim of this course is to provide students with broader and deeper knowledge as well as hands-on experience in understanding security techniques and methods needed in software development. Students complete an independent research project which will involve synthesizing multiple software security techniques and applying them to an actual software program or system.
Credit 3 units. EN: TU

E81 CSE 543T Algorithms for Nonlinear Optimization
The course will provide an in-depth coverage of modern algorithms for the numerical solution of multidimensional optimization problems. Unconstrained optimization techniques including Gradient methods, Newton's methods, Quasi-Newton methods, and conjugate methods will be introduced. The emphasis is on constrained optimization techniques: Lagrange theory, Lagrangian methods, penalty methods, sequential quadratic programming, primal-dual methods, duality theory, nondifferentiable dual methods, and decomposition methods. The course will also discuss applications in engineering systems and use of state-of-the-art computer codes. Special topics may include large-scale systems, parallel optimization, and convex optimization. Prerequisites: Calculus I and Math 309.

Credit 3 units. EN: BME T, TU

E81 CSE 544A Special Topics in Application
The material for this course varies among offerings, but this course generally covers advanced or specialized topics in computer application.
Credit 3 units. EN: BME T, TU

E81 CSE 544M Special Topics in Machines
The material for this course varies among offerings, but this course generally covers advanced or specialized topics in computer science machines.
EN: BME T, TU

E81 CSE 544S Special Topics in Systems
The material for this course varies among offerings, but this course generally covers advanced or specialized topics in computer science systems.
Credit 3 units. EN: BME T, TU

E81 CSE 544T Special Topics in Computer Science Theory
The material for this course varies among offerings, but this course generally covers advanced or specialized topics in computer science theory.
Credit 3 units. EN: BME T, TU

E81 CSE 546T Computational Geometry
Computational geometry is the algorithmic study of problems that involve geometric shapes such as points, lines, and polygons. Such problems appear in computer graphics, vision, robotics, animation, visualization, molecular biology, and geographic information systems. This course covers data structures that are unique to geometric computing, such as convex hull, Voronoi diagram, Delaunay triangulation, arrangement, range searching, KD-trees, and segment trees. Also covered are algorithms for polygon triangulation, path planning, and the art gallery problem. Prerequisite: CSE 347.
Credit 3 units.

E81 CSE 549T Theory of Parallel Systems
The course covers various aspects of parallel programming such as algorithms, schedulers and systems from a theoretical perspective. We will cover both classic and recent results in parallel computing. Topics include parallel algorithms and analysis in the work/span model, scheduling algorithms, external memory algorithms and their analysis, cache-coherence protocols, etc. The focus will be on design and analysis. Prerequisite: CSE 247.
Credit 3 units. EN: BME T, TU

E81 CSE 554A Geometric Computing for Biomedicine
With the advance of imaging technologies deployed in medicine, engineering and science, there is a rapidly increasing amount of spatial data sets (e.g., images, volumes, point clouds) that need to be processed, visualized, and analyzed. This course will focus on a number of geometry-related computing problems that are essential in the knowledge discovery process in various spatial-data-driven biomedical applications. These problems include visualization, segmentation, mesh construction and processing, and shape representation and analysis. This course consists of lectures that cover theories and algorithms, and it includes a series of hands-on programming projects using real-world data collected by various imaging techniques (e.g., CT, MRI, electron cryomicroscopy). Prerequisites: CSE 332 (or proficiency in programming in C++ or Java or Python) and CSE 247.
Credit 3 units. EN: BME T, TU

E81 CSE 555A Computational Photography
Computational Photography describes the convergence of computer graphics, computer vision, and the internet with photography.
Its goal is to overcome the limitations of traditional photography using computational techniques to enhance the way we capture, manipulate and interact with visual media. In this course we study many interesting, recent image-based algorithms and implement them to the degree that is possible. Topics may include: cameras and image formation, human visual perception, image processing (filtering, pyramids), image blending and compositing, image retargeting, texture synthesis and transfer, image completion/inpainting, super-resolution, deblurring, denoising, image-based lighting and rendering, high dynamic range, depth and defocus, flash/no flash photography, coded aperture photography, single/multiview reconstruction, photo quality assessment, non photorealistic rendering, modeling and synthesis using internet data, and others. Prerequisites: CSE 452A, CSE 554A, or CSE 559A.
Credit 3 units. EN: BME T, TU

E81 CSE 555T Adversarial AI
This course will introduce students to concepts, theoretical foundations, and applications of adversarial reasoning in Artificial Intelligence. Topics will include the use of machine learning in adversarial settings, such as security, common attacks on machine learning models and algorithms, foundations of game theoretic modeling and analysis in security, with a special focus on algorithmic approaches, and foundations of adversarial social choice, with a focus on vulnerability analysis of elections. Prerequisite: CSE417T
Credit 3 units. EN: BME T, TU

E81 CSE 556A Human-Computer Interaction Methods
An introduction to user centered design processes. The course covers a variety of HCI techniques for use at different stages in the software development cycle, including techniques that can be used with and without users. Students will gain experience using these techniques through in-class exercises and then apply them in greater depth through a semester long interface development project. Students who enroll in this course are expected to be comfortable with building user interfaces in at least one framework and be willing to learn whatever framework is most appropriate for their project. Over the course of the semester, students will be expected to present their interface evaluation results through written reports and in class presentations. Prerequisites: 3xxS or 4xxS.
Credit 3 units. EN: BME T, TU

E81 CSE 557A Advanced Visualization
We are in an era where it is possible to have all of the world's information at our fingertips. However, the more information we can access, the more difficult it is to obtain a holistic view of the data or to determine what's important to make decisions. Computer-based visualization systems provide the opportunity to represent large or complex data visually to aid comprehension and cognition. In this course, we learn about the state of the art in visualization research and gain hands-on experience with the research pipeline. We also learn how to critique existing work and how to formulate and explore sound research questions. We will cover advanced visualization topics including user modeling, adaptation, personalization, perception, and visual analytics for non-experts. Prerequisite: CSE 457A or permission of instructor.
Credit 3 units. EN: BME T, TU

E81 CSE 559A Computer Vision
This course introduces the fundamentals of designing computational systems that can "look at" images and reason about the physical objects and scenes they represent. Topics include the estimation of color, shape, geometry, and motion from images; image classification, segmentation, and object detection; and image restoration, enhancement, and synthesis. The focus of this course will be on mathematical foundations and practical algorithmic approaches, including: the physics and geometry of image formation; robust methods for estimating image motion and geometry; and deep-learning approaches for semantic image understanding. Students will be required to program in Python. Prerequisites: Any of: CSE 417T (ML), ESE417 (ML), CSE514A (Data Mining), CSE517A (ML).
Credit 3 units. EN: BME T, TU

E81 CSE 560M Computer Systems Architecture I
An exploration of the central issues in computer architecture: instruction set design, addressing and register set design, control unit design, memory hierarchies (cache and main memories, virtual memory), pipelining, instruction scheduling, and parallel systems. The course emphasizes understanding the performance implications of design choices, using architecture modeling and evaluation using simulation techniques. Prerequisites: CSE 361S and CSE 260M.
Credit 3 units. EN: BME T, TU

E81 CSE 563M Digital Integrated Circuit Design and Architecture
This is a project-oriented course on digital VLSI design. The course material focuses on bottom-up design of digital integrated circuits, starting from CMOS transistors, CMOS inverters, combinational circuits and sequential logic designs. Important design aspects of digital integrated circuits such as propagation delay, noise margins and power dissipation are covered in the class, and design challenges in sub-micron technology are addressed. The students design combinational and sequential circuits at various levels of abstraction using a state-of-the-art CAD environment provided by Cadence Design Systems. The goal of the course is to design a microprocessor in 0.5 micron technology that will be fabricated by a semiconductor foundry. Prerequisites: CSE 260M and ESE 232.
Same as E81 CSE 463M
Credit 3 units. EN: BME T, TU

E81 CSE 566S High Performance Computer Systems
Many applications make substantial performance demands upon the computer systems upon which those applications are deployed. In this context, performance is frequently multidimensional, including resource efficiency, power, execution speed (which can be quantified via elapsed run time, data throughput, or latency), and so on. Modern computing platforms exploit parallelism and architectural diversity (e.g., co-processors such as graphics engines and/or reconfigurable logic) to achieve the desired performance goals. This course addresses the practical aspects of achieving high performance on modern computing platforms. This includes questions ranging from how the computing platform is designed to how are applications and algorithms expressed to exploit the platform's properties. Particular attention is given to the role of application development tools. Prerequisite: familiarity with software development in Linux preferred, graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E81 CSE 567M Computer Systems Analysis
A comprehensive course on performance analysis techniques. The topics include common mistakes, selection of techniques and metrics, summarizing measured data, comparing systems using random data, simple linear regression models, other regression models, experimental designs, 2**k experimental designs, factorial designs with replication, fractional factorial designs, one factor experiments, two factor full factorial design w/o replications, two factor full factorial designs with replications, general full factorial designs, introduction to queueing theory, analysis of single queues, queueing networks, operational laws, mean-value analysis, time series analysis, heavy tailed distributions, self-similar processes, long-range dependence, random number generation, analysis of simulation results, and art of data presentation. Prerequisites: CSE 260M.
Credit 3 units. EN: BME T, TU

E81 CSE 569S Recent Advances in Computer Security and Privacy
The aim of this course is to provide students with knowledge and hands-on experience in understanding the security techniques and methods needed for IoT, real-time, and embedded systems. Students complete an independent research project which will involve synthesizing multiple security techniques and applying them to an actual IoT, real-time, or embedded system or device.
Credit 3 units. EN: BME T, TU

E81 CSE 570S Recent Advances in Networking
This course covers the latest advances in networking. The topics include Networking Trends, Data Center Network Topologies, Data Center Ethernet, Server Virtualization, Storage Virtualization, Carrier Ethernet, Application Delivery Networking, Virtual Bridging, Big Data, Networking Issues for Big Data, LAN Extension and Virtualization using Layer 3 Protocols, Multi-Tenant Isolation and Network Virtualization in Cloud Data Centers, OpenFlow, OpenFlow Controllers and Tools, Software Defined Networking (SDN), Network Function Virtualization (NFV), Internet of Things (IoT), Networking Protocols for IoT, Blockchains, and Quantum Communications. Students also do a project/survey involving application of these topics.
Credit 3 units. EN: BME T, TU

E81 CSE 571S Network Security
This course covers principles and techniques in securing computer networks. Real world examples will be used to illustrate the rationales behind various security designs. There are three main components in the course, preliminary cryptography, network protocol security and network application security. Topics include IPSec, SSL/TLS, HTTPS, network fingerprinting, network malware, anonymous communication, and blockchain. The class project allows students to take a deep dive into a topic of choice in network security. Prerequisite: CSE 473S.
Credit 3 units. EN: BME T, TU

E81 CSE 574S Recent Advances in Wireless and Mobile Networking
This course provides a comprehensive treatment of wireless data and telecommunication networks. Topics include recent trends in wireless and mobile networking, wireless coding and modulation, wireless signal propagation, IEEE 802.11a/b/g/n/ac wireless local area networks, 60 GHz millimeter wave gigabit wireless networks, vehicular wireless networks, white spaces, Bluetooth and Bluetooth Smart, wireless personal area networks, wireless protocols for the Internet of Things, cellular networks: 1G/2G/3G, LTE, LTE-Advanced, and 5G. Prerequisite: CSE 473S (Introduction to Computer Networks) or permission of instructor.
Credit 3 units. EN: BME T, TU

E81 CSE 581T Approximation Algorithms
Numerous optimization problems are intractable to solve optimally. The intractability of a problem could come from the problem's computational complexity, for instance the problem is NP-Hard, or other computational barriers. To cope with the inability to find an optimal algorithm, one may desire an algorithm that is guaranteed to return a solution that is comparable to the optimum. Such an algorithm is known as an approximation algorithm. Approximation algorithms are a robust way to cope with intractability, and they are widely used in

practice or are used to guide the development of practical heuristics. The area of approximation algorithms has developed a vast theory, revealing the underlying structure of problems as well as their different levels of difficulty. The majority of this course will focus on fundamental results and widely applicable algorithmic and analysis techniques for approximation algorithms. Prerequisite: CSE 347.
Credit 3 units. EN: BME T, TU

E81 CSE 584A Algorithms for Biosequence Comparison
This course surveys algorithms for comparing and organizing discrete sequential data, especially nucleic acid and protein sequences. Emphasis is on tools to support search in massive biosequence databases and to perform fundamental comparison tasks such as DNA short-read alignment. Prerequisite: CSE 347 or permission of instructor. These techniques are also of interest for more general string processing and for building and mining textual databases. Algorithms are presented rigorously, including proofs of correctness and running time where feasible. Topics include classical string matching, suffix array string indices, space-efficient string indices, rapid inexact matching by filtering (including BLAST and related tools), and alignment-free algorithms. Students complete written assignments and implement advanced comparison algorithms to address problems in bioinformatics. This course does not require a biology background. Prerequisite: CSE 347 or permission of instructor.
Credit 3 units. EN: BME T, TU

E81 CSE 586A Analysis of Imaging Data
This course focuses on an in-depth study of advanced topics and interests in image data analysis. Students will learn about hardcore imaging techniques and gain the mathematical fundamentals needed to build their own models for effective problem solving. Topics of deformable image registration, numerical analysis, probabilistic modeling, data dimensionality reduction, and convolutional neural networks for image segmentation will be covered. The main focus might change from semester to semester. Prerequisites: Math 309, ESE 326, and CSE 247.
Credit 3 units.

E81 CSE 587A Algorithms for Computational Biology
This course is a survey of algorithms and mathematical methods in biological sequence analysis (with a strong emphasis on probabilistic methods) and systems biology. Sequence analysis topics include introduction to probability, probabilistic inference in missing data problems, hidden Markov models (HMMs), sequence alignment, and identification of transcription-factor binding sites. Systems biology topics include the mapping of gene regulatory networks, quantitative modeling of gene regulatory networks, synthetic biology, and applications of deep learning in computational biology. Prerequisite: CSE 131 or CSE 501N.
Credit 3 units. EN: BME T, TU

E81 CSE 591 Introduction to Graduate Study in CSE
Introduces students to the different areas of research conducted in the department. Provides an introduction to research skills, including literature review, problem formulation, presentation, and research ethics. Lecture and discussion are supplemented by exercises in the different research areas and in critical reading, idea generation, and proposal writing.
Credit 3 units.

E81 CSE 598 Master's Project
Students electing the project option for their master's degree perform their project work under this course. In order to successfully complete this course, students must defend their project before a three-person committee and present a 2-3 page extended abstract. Prerequisite: permission of advisor and submission of a research proposal form.
Credit variable, maximum 6 units.

E81 CSE 599 Master's Research
Students electing the thesis option for their master's degree perform their thesis research under this course. In order to successfully complete a master's thesis, students must enroll in 6 units of this course typically over the course of two consecutive semesters, produce a written thesis, and defend the thesis before a three-person committee. Prerequisite: permission of advisor and submission of a research proposal form.
Credit variable, maximum 6 units.

E81 CSE 637S Software Security
In this course, students will be introduced to the foundations of software security. We will explore different classes of software vulnerabilities and analyze the fundamental problems behind these vulnerabilities, and we will study the methods and techniques used to discover, exploit, prevent, and mitigate these vulnerabilities. Topics of interest include buffer overflow, integer overflow, type confusion, use-after-free, and so on. Throughout the course, we take a defense-in-depth mentality and see how systems can be protected. Students are expected to have a solid understanding of assembly language, C/C++, and operating systems. Prerequisite: CSE 361S.
Credit 3 units.

E81 CSE 659A Advances in Computer Vision
Computer vision is a fast-moving field, with the past few years seeing tremendous advances in the development of computational algorithms for solving visual tasks. This course is designed to introduce students to advanced and recently published techniques for problems in low-level vision, recognition and classification, and computational photography. Prerequisite: CSE 559A.
Credit 3 units.

E81 CSE 699 Doctoral Research
Credit variable, maximum 9 units.

E81 CSE 7001 Research Seminar on Computer Science Pedagogy
This seminar will examine research, techniques, approaches, and strategies for teaching computer science at the undergraduate and graduate levels. Participants will take turns presenting a particular paper or concept and then leading an ensuing discussion. While this seminar may be especially helpful for those contemplating an academic career, the seminar is open to all interested participants.
Credit 1 unit.

E81 CSE 7100 Research Seminar on Machine Learning
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7200 Research Seminar on Robotics and Human-Computer Interaction
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7300 Research Seminar on Software Systems
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7400 Research Seminar on Algorithms and Theory
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7500 Research Seminar on Graphics and Vision
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7600 Research Seminar on Analog Computing
This seminar will focus on classic and recent papers on analog, stochastic and neuromorphic computing. Students will read, present, and discuss journal papers on analog techniques for implementing sensors and processors. Focus will be placed on fundamental advances and challenges of implementing analog processors. No prerequisites.
Credit 1 unit.

E81 CSE 7700 Research Seminar on Networking and Communications
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7800 Research Seminar on Computational Systems Biology
Research seminars examine publications, techniques, approaches and strategies within an area of computer science and engineering. Seminars are highly participational: Students are expected to take turns presenting material, to prepare for seminar by reading any required material, and to contribute to the group's discussions. The actual topics covered in a seminar will vary by semester and instructor. Interested students are encouraged to obtain a syllabus from the instructor's webpage or by contacting the instructor.
Credit 1 unit.

E81 CSE 7900 Research Seminar on Parallel Computing
This seminar will focus on classic and recent papers on parallel computing. Students will read, present and discuss papers on parallel models, algorithms and architectures from top conferences and journals. Focus will be placed on fundamental advances and theoretical models and algorithms, rather than on implementation papers. No prerequisites.
Credit 1 unit.

E81 CSE 801 Pedagogy
A student taking this course studies the fundamentals of teaching in the discipline of computer science and computer engineering. A student enrolled in this course staffs some other course taught by our department, serving as its primary instructor or co-instructor. That student receives frequent mentoring and feedback on preparation and delivery. This course is recommended especially for doctoral students who seek a career in computer science and engineering education.
Credit 3 units.

PhD in Computer Science or Computer Engineering

Students can choose to pursue a PhD in Computer Science or a PhD in Computer Engineering. The requirements vary for each degree. Here are the core requirements:

- Complete 72 units of regular — including graded — courses (at least 33 units, of which 9 must fulfill breadth requirements), seminars (at least 3 units), and research credits (at least 24 units).
- Satisfy fundamental teaching requirements by participating in mentored teaching experiences and complete scholarly communication requirements by participating in the Doctoral Student Research Seminar.
- Pass milestones that demonstrate the ability to understand research literature, to communicate orally and in writing, and to formulate a detailed research plan. These milestones include an oral qualifying examination, a dissertation proposal defense, and a dissertation defense.

For more information, please refer to the Doctoral Program Guide available on the Computer Science & Engineering website (https://cse.wustl.edu/graduate/programs/Pages/phd-programs.aspx).

Master of Science (MS) in Computer Science

The Master of Science (MS) in Computer Science is directed toward students with a computer science background who are looking for a program and courses that are more focused on software. This can be either a pure course option program, or it can incorporate either a project or a thesis. If a student chooses a degree option that incorporates a research experience, this MS degree may provide a solid stepping stone to future doctoral studies. All students in the MS in Computer Science program must have previously completed (as documented by their undergraduate transcript), successfully test to place out of, or complete at the start of their program the following courses: CSE 501N Introduction to Computer Science and CSE 502N Data Structures and Algorithms (or equivalent courses offered at other institutions).

Course Option

This option requires 30 units of graduate credit. Students must also follow the general degree requirements listed below and complete the breadth requirements.

Thesis/Project Option

The thesis and project options require 24 units of graduate credit in addition to 6 units of either thesis or project courses (CSE 599 or CSE 598, respectively). Students pursuing the project option may opt to take 27 units of graduate courses and only 3 units of CSE 598, with advisor approval. Students must also follow the general degree requirements listed below. Thesis students are exempt from the breadth requirements.

General Degree Requirements

- Breadth requirements include one departmental course from each of the following categories: Theory (T), Software Systems (S), and either Machines (M) or Applications (A). These courses must be at the 500 level or above.
- 18 of the 30 required units must be CSE departmental courses at the 500 level or above.
- Students may count up to 6 units of course work taken outside the CSE department toward their degree. Out-of-department courses must be individually reviewed and approved by the department to ensure that they offer suitably technical graduate-level content. No more than 6 out-of-department units may be counted except in extraordinary circumstances, and no more than 12 units may be counted in any case.
- Up to 12 units of 400-level courses can count for graduate credit.
- None of of the 30 units may be taken as independent study (i.e., CSE 400 or CSE 500).
- Courses with an "N" designation do not count toward the master's degree.
- All 30 units required for the degree must be taken for a grade (i.e., not pass/fail), and the grade received in each course must be C- or better.
- Per School of Engineering guidelines, students must maintain a grade-point average of at least 2.70.

Master of Science (MS) in Computer Engineering

The Master of Science (MS) in Computer Engineering is best suited for students who are looking to focus on computer engineering (hardware) aspects. The MS in Computer Engineering program can be a pure course option program, or it can incorporate either a project or a thesis. If appropriate research experiences are included in the degree option, this can also lead toward future doctoral studies. All students in the MS in Computer Engineering program must have previously completed (as documented by their undergraduate transcript), successfully test to place out of, or complete at the start of their program the following courses: CSE 501N Introduction to Computer Science and CSE 505N Introduction to Digital Logic and Computer Design (or equivalent courses offered at other institutions).

The Master of Science in Computer Engineering degree is jointly administered by the Department of Computer Science and Engineering and the Department of Electrical and Systems Engineering

Course Option

This option requires 30 units of graduate credit. Students must also follow the general degree requirements listed below.

Thesis/Project Option

The thesis and project options require 24 units of graduate credit in addition to 6 units of either thesis or project courses (CSE/ESE 599 or CSE 598, respectively). Students pursuing the project option may opt to take 27 units of graduate courses and only 3 units of CSE 598, with advisor approval. Students must also follow the general degree requirements listed below.

General Degree Requirements

- 18 of the 30 units must be from the designated graduate-level Computer Engineering courses. Please visit our MS in Computer Engineering website (https://cse.wustl.edu/graduate/programs/Pages/ms-in-computer-engineering.aspx) for a comprehensive list.
- Up to 12 units may be taken from outside the two departments. Such approval will be contingent on the credits being for suitably technical graduate-level content. To count more than 6 units from outside the CSE or ESE department, an appropriate justification for the additional increment must be provided by the advisor and student. Program approval will be evaluated with increasing stringency for each additional increment.
- Up to 12 units of 400-level courses can count for graduate credit.
- None of of the 30 units may be taken as independent study (i.e., CSE 400, CSE 500, ESE 400, or ESE 500).

- CSE courses with an "N" designation do not count toward the master's degree.
- All 30 units required for the degree must be taken for a grade (i.e., not pass/fail), and the grade received in each course must be C- or better.
- Per McKelvey School of Engineering guidelines, students must maintain a grade-point average of at least 2.70.

Master of Science (MS) in Cybersecurity Engineering

The Master of Science (MS) in Cybersecurity Engineering at Washington University will give students the skills, knowledge and expertise needed to work in the rapidly growing field of cybersecurity and to design, engineer and architect cybersecurity technology and systems. Graduates of this program will be equipped with the theoretical and hands-on engineering expertise required to solve complex cybersecurity problems that affect diverse enterprises worldwide.

The program includes a set of core foundational courses that focus on operating systems as well as network and systems security. Students pursuing this degree may also choose from more advanced cybersecurity elective courses that will build deeper integrative knowledge of key concepts. Work in the program culminates in either a capstone project or a final thesis. The capstone project should focus on a specific set of technical cybersecurity challenges, with the objective of designing an implementable solution to those challenges. The thesis option allows students to plan, execute and report on an individual project that addresses a substantial problem, covering both practical and scientific aspects. Students planning to pursue a PhD degree after completing the MS in Cybersecurity degree are particularly encouraged to pick the thesis option.

All students in the MS in Cybersecurity Engineering program must have previously completed (as documented by their undergraduate transcript), successfully tested to place out of, or completed at the start of their program the following courses: CSE 501N Introduction to Computer Science and CSE 502N Data Structures and Algorithms (or equivalent courses offered at other institutions).

Core Courses

Code	Title	Units
CSE 422S	Operating Systems Organization	3
CSE 433S	Introduction to Computer Security	3
CSE 473S	Introduction to Computer Networks	3
CSE 523S	Systems Security	3
Total Units		**12**

Program Electives

Choose three courses:

Code	Title	Units
CSE 434S	Reverse Engineering and Malware Analysis	3
CSE 522S	Advanced Operating Systems	3
CSE 544T	Special Topics in Computer Science Theory	3
CYBER 565	Cybersecurity Analytics	3
CYBER 566	Cybersecurity Risk Management	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3
CSE 569S	Recent Advances in Computer Security and Privacy	3
CSE 571S	Network Security	3
CSE 637S	Software Security	3

Culminating Experience

Choose one of the following:

Code	Title	Units
CSE 598	Master's Project	6
CSE 599	Master's Research	6
(6 units required, typically completed over the course of two semesters)		

General Degree Requirements

- Students who have already taken core or elective courses specified by the program can, with departmental approval, substitute other courses that are suitably technical and appropriate to the degree program. Departmental approval will require justification and will be evaluated with increasing stringency for each additional substitution.
- None of of the 30 units may be taken as independent study (i.e., CSE 400 or CSE 500).
- Courses with an "N" designation do not count toward the master's degree.
- All courses must be taken for a grade of C- or better.
- As per McKelvey School of Engineering guidelines, students must maintain a grade-point average of at least 2.70.

Master of Engineering (MEng) in Computer Science and Engineering

The Master of Engineering (MEng) in Computer Science and Engineering is specifically designed for students who would like to combine studies in computer science and computer engineering (possibly in conjunction with graduate-level work in another discipline) or who, for other reasons, need a more flexible structure for their master's studies. The MEng offers more flexibility by allowing approved outside courses (i.e., courses not specifically taken in computer science, such as various business courses) to count toward the degree; in this manner, an MEng student can customize their program by incorporating interdisciplinary components, when and if these are approved by the faculty advisor. Work in the program culminates in a capstone project highlighting each student's ambitions, interests, and accomplishments in the program. MEng students typically move directly into the industry. All students in the MEng program must have previously completed (as documented by their undergraduate transcript), successfully tested to place out of, or completed at the start of their program the following courses: CSE 501N Introduction to Computer Science and CSE 502N Data Structures and Algorithms (or equivalent courses offered at other institutions).

Degree Requirements

- The MEng requires 30 total units, including 24 units of graduate-level course work and 6 units of CSE 598 Master's Project work culminating in a successful project defense.
- 12 of the 24 units must be CSE departmental courses at the 400 level or above. Of these 12 units, 9 units must be at the 500 level or above.
- Students may count up to 12 units of course work taken outside the Computer Science & Engineering Department toward their degree. To count more than 6 such units, the student and their faculty advisor must justify how the outside units contribute to a coherent, interdisciplinary plan of study, which must be reviewed and approved by the department. Increasing justification will be required as the number of outside units increases. In addition, each out-of-department course must be individually reviewed and approved by the department to ensure that it offers suitably technical graduate-level content.
- Up to 15 units of 400-level courses can count for graduate credit.
- None of the 30 units may be taken as independent study (i.e., CSE 400 or CSE 500).
- CSE courses with an "N" designation do not count toward the master's degree.
- All 30 units required for the degree must be taken for a grade (i.e., not pass/fail), and the grade received in each course must be C- or better.
- Per McKelvey School of Engineering guidelines, students must maintain a grade-point average of at least 2.70.

Certificate in Data Mining and Machine Learning

The Certificate in Data Mining and Machine Learning can be awarded in conjunction with any engineering master's degree. To qualify for this certificate, students enrolled in any master's in engineering program will need to meet the requirements listed below in addition to the standard requirements for their master's degree.

Required Courses

Code	Title	Units
CSE 417T	Introduction to Machine Learning	3
or ESE 417	Introduction to Machine Learning and Pattern Classification	
CSE 517A	Machine Learning	3
CSE 541T	Advanced Algorithms	3
Total Units		**9**

Foundations Courses

Choose two courses:

Code	Title	Units
CSE 412A	Introduction to Artificial Intelligence	3
CSE 513T	Theory of Artificial Intelligence and Machine Learning	3
CSE 514A	Data Mining	3
CSE 515T	Bayesian Methods in Machine Learning	3
CSE 519T	Advanced Machine Learning	3
CSE 543T	Algorithms for Nonlinear Optimization	3
ESE 415	Optimization	3
Math 493	Probability	3
or ESE 520	Probability and Stochastic Processes	
Math 494	Mathematical Statistics	3

Domain Courses

Choose one course:

Code	Title	Units
CSE 427S	Cloud Computing with Big Data Applications	3
CSE 518A	Human-in-the-Loop Computation	3
CSE 527A	Natural Language Processing	3
CSE 534A	Large-Scale Optimization for Data Science	3
CSE 557A	Advanced Visualization	3
CSE 559A	Computer Vision	3
CSE 584A	Algorithms for Biosequence Comparison	3
CSE 587A	Algorithms for Computational Biology	3

Additional Information

- All courses must be taken for a grade.
- Students with previous courses in machine learning may place out of CSE 417T. These students will be required to complete an additional foundations course for a total of three foundations courses.

- Students who began the certificate prior to FL16 who have successfully completed CSE 517A, independent of CSE 417T, will be required to complete an additional foundations course in place of CSE 417T for a total of three foundations courses. No student will be allowed to take CSE 417T after the successful completion of CSE 517A.
- Any student who began the certificate prior to FL16 may use CSE 441T in place of CSE 541T.

Certificate in Cybersecurity Engineering

The Certificate in Cybersecurity Engineering can be awarded in conjunction with any engineering master's degree. In order to qualify for this certificate, students enrolled in any master's in engineering program will need to meet the requirements listed below in addition to the standard requirements for their master's degree.

Core Courses

Code	Title	Units
CSE 433S	Introduction to Computer Security	3
CSE 523S	Systems Security	3
CSE 571S	Network Security	3
CSE 637S	Software Security	3

Program Electives

Choose one:

Code	Title	Units
CSE 544T	Special Topics in Computer Science Theory	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3
CSE 422S	Operating Systems Organization	3
CSE 522S	Advanced Operating Systems	3

Electrical & Systems Engineering

The Department of Electrical & Systems Engineering offers doctoral-level and master's-level degrees in Electrical Engineering and in Systems Science & Mathematics. At the doctoral level, both the PhD and DSc degrees are available; these typically require four to five years of full-time study leading to an original research contribution. At the master's level, the programs require 30 credit units of study and have both a course option and a thesis option.

Research activity in the department is focused in the following four areas:

Applied Physics

- Nanophotonics
- Quantum optics
- Engineered materials
- Electrodynamics

Devices & Circuits

- Computer engineering
- Integrated circuits
- Radiofrequency circuits
- Sensors

Systems Science

- Optimization
- Applied mathematics
- Control
- Financial engineering

Signals & Imaging

- Computational imaging
- Signal processing
- Optical imaging
- Data sciences

Students working in any of these areas will enjoy the benefits of programs that balance fundamental theoretical concepts with modern applications. In our department, students find ample opportunities for close interactions with faculty members working on cutting-edge research and technology development.

Prospective PhD students with previous degrees in engineering who are interested in PhD studies and research in mathematics or statistics are encouraged to apply for PhD studies in Mathematics and Statistics. For more details, visit the Graduate Programs in Mathematics and Statistics (http://wumath.wustl.edu/graduate/) webpage.

Phone:	314-935-5565
Website:	https://ese.wustl.edu/academics/graduate-programs/index.html

Faculty

Chair

Bruno Sinopoli (https://engineering.wustl.edu/Profiles/Pages/Bruno-Sinopoli.aspx)
Das Family Distinguished Professor
PhD, University of California, Berkley
Cyberphysical systems, analysis and design of networked embedded control systems, with applications to sensor actuators networks

Endowed Professors

Shantanu Chakrabartty (https://engineering.wustl.edu/faculty/Shantanu-Chakrabartty.html)
Clifford W. Murphy Professor
PhD, Johns Hopkins University
New frontiers in unconventional analog computing techniques using silicon and hybrid substrates, fundamental limits of energy efficiency, sensing and resolution by exploiting computational and adaptation primitives inherent in the physics of devices

Arye Nehorai (https://engineering.wustl.edu/faculty/Arye-Nehorai.html)
Eugene and Martha Lohman Professor of Electrical Engineering
PhD, Stanford University
Statistical signal processing, machine learning, imaging, biomedicine

Joseph A. O'Sullivan (https://engineering.wustl.edu/faculty/Joseph-OSullivan.html)
Samuel C. Sachs Professor of Electrical Engineering
Dean, UMSL/WashU Joint Undergraduate Engineering Program
PhD, Notre Dame University
Information theory, statistical signal processing, imaging science with applications in medicine and security, and recognition theory and systems

Lan Yang (https://engineering.wustl.edu/faculty/Lan-Yang.html)
Edward H. & Florence G. Skinner Professor of Engineering
PhD, California Institute of Technology
Nano/micro photonics, ultra high-quality optical microcavities, ultra-low-threshold microlasers, nano/micro fabrication, optical sensing, single nanoparticle detection, photonic molecules, photonic materials

Professors

Jr-Shin Li (https://engineering.wustl.edu/faculty/Jr-Shin-Li.html)
Professor
PhD, Harvard University
Mathematical control theory, optimization, quantum control, biomedical applications

Neal Patwari (https://engineering.wustl.edu/faculty/Neal-Patwari.html)
Professor
PhD, University of Michigan
Intersection of statistical signal processing and wireless networking for improving wireless sensor networking and radiofrequency sensing

Associate Professors

ShiNung Ching (https://engineering.wustl.edu/faculty/ShiNung-Ching.html)
PhD, University of Michigan
Systems and control in neural medicine, nonlinear and constrained control, physiologic network dynamics, stochastic control

Andrew Clark (https://engineering.wustl.edu/faculty/Andrew-Clark.html)
PhD, University of Washington
Focused on control and security of networked and cyber-physical systems

Matthew D. Lew (https://engineering.wustl.edu/faculty/Matthew-Lew.html)
PhD, Stanford University
Microscopy, biophotonics, computational imaging, nano-optics

Jung-Tsung Shen (https://engineering.wustl.edu/faculty/Jung-Tsung-Shen.html)
PhD, Massachusetts Institute of Technology
Theoretical and numerical investigations on nanophotonics, optoelectronics, plasmonics, metamaterials

Yong Wang (https://engineering.wustl.edu/faculty/Yong-Wang.html)
PhD, Washington University in St. Louis
Biomedical engineering, life science, human physiology, magnetic resonance imaging, electrocardiographic imaging

Xuan "Silvia" Zhang (https://engineering.wustl.edu/faculty/Xuan-Silvia-Zhang.html)
PhD, Cornell University
Robotics, cyber-physical systems, hardware security, ubiquitous computing, embedded systems, computer architecture, VLSI, electronic design automation, control optimization, biomedical devices and instrumentation

Assistant Professors

Ulugbek Kamilov (https://engineering.wustl.edu/faculty/Ulugbek-Kamilov.html)
PhD, École Polytechnique Fédérale de Lausanne, Switzerland
Computational imaging, signal processing, biomedical imaging

Ioannis (Yiannis) Kantaros (https://engineering.wustl.edu/faculty/Yiannis-Kantaros.html)
PhD, Duke University
Designs safe and distributed autonomy algorithms for large-scale multi-robot systems

Mark Lawrence
PhD, University of Birmingham
Nanophotonics, nonlinear optics, metasurfaces

Aravind Nagulu (https://engineering.wustl.edu/faculty/Aravind-Nagulu.html)
PhD, Columbia University
Pioneering the area of novel wave propagation based on time-variance

Chuan Wang (https://engineering.wustl.edu/faculty/Chuan-Wang.html)
PhD, University of Southern California
Flexible electronics, stretchable electronics, printed electronics, nanomaterials, nanoelectronics, optoelectronics

Shen Zeng (https://engineering.wustl.edu/faculty/Shen-Zeng.html)
PhD, University of Stuttgart
Systems and control theory, data-based analysis and control of complex dynamical systems, inverse problems, biomedical applications

Senior Professors

Paul S. Min (https://engineering.wustl.edu/faculty/Paul-Min.html)
PhD, University of Michigan
Routing and control of telecommunication networks, fault tolerance and reliability, software systems, network management

Robert E. Morley Jr. (https://engineering.wustl.edu/faculty/Robert-Morley.html)
DSc, Washington University in St. Louis
Computer engineering, lower-power VLSI design, computer architecture, signal processing, microprocessors systems design

Hiro Mukai (https://engineering.wustl.edu/faculty/Hiro-Mukai.html)
PhD, University of California, Berkeley
Theory and computational methods for optimization, optimal control, systems theory, electric power system operations, differential games

William F. Pickard (https://engineering.wustl.edu/faculty/William-Pickard.html)
PhD, Harvard University
Biological transport, electrobiology, energy engineering

Daniel L. Rode (https://engineering.wustl.edu/faculty/Daniel-Rode.html)
PhD, Case Western Reserve University
Optoelectronics and fiber optics, semiconductor materials, light-emitting diodes and lasers, semiconductor processing, electronics

Ervin Y. Rodin (https://engineering.wustl.edu/faculty/Ervin-Rodin.html)
PhD, University of Texas at Austin
Optimization, differential games, artificial intelligence, mathematical modeling

Heinz Schaettler (https://engineering.wustl.edu/faculty/Heinz-Schaettler.html)
PhD, Rutgers University
Optimal control, nonlinear systems, mathematical models in biomedicine

Barbara A. Shrauner (https://engineering.wustl.edu/faculty/Barbara-Shrauner.html)
PhD, Harvard University (Radcliffe)
Plasma processing, semiconductor transport, symmetries of nonlinear differential equations

Barry E. Spielman (https://engineering.wustl.edu/faculty/Barry-Spielman.html)
PhD, Syracuse University
High-frequency/high-speed devices, radiofrequency and microwave integrated circuits, computational electromagnetics

Tzyh Jong Tarn (https://engineering.wustl.edu/faculty/TJ-Tarn.html)
DSc, Washington University
Quantum mechanical systems, bilinear and nonlinear systems, robotics and automation, life science automation

Professors of Practice

Dedric Carter (https://engineering.wustl.edu/faculty/Dedric-Carter.html)
PhD, Nova Southeastern University
MBA, MIT Sloan School of Management

Dennis Mell (https://engineering.wustl.edu/faculty/Dennis-Mell.html)
MS, University of Missouri–Rolla
Industrial automation, robotics and mechatronics, product design and development with design-for-manufacturability emphasis, prototyping, manufacturing

Ed Richter (https://engineering.wustl.edu/faculty/Ed-Richter.html)
MS, Washington University
Signal processing applications implemented on a variety of platforms, including ASIC, FPGA, DSP, microcontroller and desktop computers

Jason Trobaugh (https://engineering.wustl.edu/faculty/Jason-Trobaugh.html)
DSc, Washington University
Ultrasound imaging, diffuse optical tomography, image-guided therapy, ultrasonic temperature imaging

Teaching Professor

James Feher (https://engineering.wustl.edu/faculty/James-Feher.html)
PhD, Missouri University of Science and Technology
Electrical engineering, computer science, mathematics and physics

Senior Lecturers

Martha Hasting (https://engineering.wustl.edu/faculty/Martha-Hasting.html)
PhD, Saint Louis University
Mathematics education

Vladimir Kurenok (https://engineering.wustl.edu/faculty/Vladimir-Kurenok.html)
PhD, Belarus State University (Minsk, Belarus)
Probability and stochastic processes, stochastic ordinary and partial differential equations, financial mathematics

Jinsong Zhang (https://engineering.wustl.edu/faculty/Jinsong-Zhang.html)
PhD, University of Miami
Modeling and performance analysis of wireless sensor networks, multi-source information fusion, ambiguous and incomplete information processing

Lecturers

Tsitsi Madziwa-Nussinov (https://engineering.wustl.edu/faculty/Tsitsi-Nussinov.html)
PhD, University of California, Los Angeles

Dorothy Wang (https://engineering.wustl.edu/faculty/Yunjing-Dorothy-Wang.html)
PhD, Virginia Tech
Fiber optic sensing and practical experience in sensor implementation and field test

Professors Emeriti

R. Martin Arthur (https://engineering.wustl.edu/faculty/Martin-Arthur.html)
Newton R. and Sarah Louisa Glasgow Wilson Professor of Engineering
PhD, University of Pennsylvania
Ultrasonic imaging, electrocardiography

David L. Elliott
PhD, University of California, Los Angeles
Mathematical theory of systems, nonlinear difference, differential equations

Degree Requirements

The Department of Electrical & Systems Engineering offers doctoral-level and master's-level degrees in Electrical Engineering and in Systems Science & Mathematics as well as a certificate in Imaging Science. At the doctoral level, both the PhD and DSc degrees are available; these typically require four to five years of full-time study leading to an original research contribution. At the master's level, the programs require a minimum of 30 units of study consistent with the residency and other applicable requirements of Washington University and McKelvey School of Engineering. The master's degrees may be pursued with a course-only option or a thesis option.

Students will enjoy the benefits of programs that balance fundamental theoretical concepts with modern applications. In our department, students will find ample opportunities for close interactions with faculty members working on cutting-edge research and technology development.

Please visit the following pages for more information about our programs:

- Doctoral Degrees (p. 62)
- Master of Science in Electrical Engineering (MSEE) (p. 62)
- Master of Science in Systems Science & Mathematics (MSSSM) (p. 63)
- Master of Science in Engineering Data Analytics and Statistics (MSDAS) (p. 64)
- Master of Science (MS) in Computer Engineering (p. 64)
- Certificate in Controls (p. 65)
- Certificate in Imaging Science & Engineering (IS&E) (p. 65)
- Certificate in Quantum Engineering (p. 67)

Courses

Visit online course listings to view semester offerings for E35 ESE (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E35&crslvl=5:8).

E35 ESE 500 Independent Study
Opportunities to acquire experience outside the classroom setting and to work closely with individual members of the faculty. A final report must be submitted to the department. Prerequisite: Students must have the ESE Research/Independent Study Registration Form approved by the department.
Credit variable, maximum 3 units.

E35 ESE 5001 Research Rotation for ESE Masters Students
Masters students in Electrical and Systems Engineering may complete a rotation their first semester with research mentors acceptable to the Department. The rotations must be mutually agreeable to both the student and faculty member. The grade will be assigned based on a written report from the rotation. The rotation allows students to sample different research projects and laboratory working environments, to enable matching masters students and research mentors with whom they will carry out thesis research.
Credit 3 units.

E35 ESE 501 Mathematics of Modern Engineering I
Matrix algebra: systems of linear equations, vector spaces, linear independence and orthogonality in vector spaces, eigenvectors and eigenvalues; vector calculus: gradient, divergence, curl, line and surface integrals, theorems of Green, Stokes, and Gauss; Elements of Fourier analysis and its applications to solving some classical partial differential equations, heat, wave, and Laplace equation. Prerequisites: ESE 318 and ESE 319 or equivalent or consent of instructor. This course will not count toward the ESE doctoral program.
Credit 3 units. EN: BME T, TU

E35 ESE 502 Mathematics of Modern Engineering II
This course covers Fourier series and Fourier integral transforms and their applications to solving some partial differential equations and heat and wave equations. It also presents complex analysis and its applications to solving real-valued problems, including analytic functions and their role, Laurent series representation, complex-valued line integrals and their evaluation (including the residual integration theory), and conformal mappings and their applications. Prerequisites: ESE 318 and ESE 319 or equivalent, or permission of instructor. This course will not count toward the ESE doctoral program.
Credit 3 units. EN: BME T, TU

E35 ESE 513 Large-Scale Optimization for Data Science
Large-scale optimization is an essential component of modern data science, artificial intelligence, and machine learning. This graduate-level course rigorously introduces optimization methods that are suitable for large-scale problems arising in these areas. Students will learn several algorithms suitable for both smooth and nonsmooth optimization, including gradient methods, proximal methods, mirror descent, Nesterov's acceleration, ADMM, quasi-Newton methods, stochastic optimization, variance reduction, and distributed optimization. Throughout the course, we will discuss the efficacy of these methods in concrete data science problems, under appropriate statistical models. Students will be required to program in Python or MATLAB. Prerequisites: CSE 247, Math 309, (Math 3200 or ESE 326), ESE 415.
Credit 3 units. EN: TU

E35 ESE 520 Probability and Stochastic Processes
This course covers a review of probability theory; models for random signals and noise; calculus of random processes; noise in linear and nonlinear systems; representation of random signals by sampling and orthonormal expansions; and Poisson, Gaussian, and Markov processes as models for engineering problems. Prerequisite: ESE 326.
Credit 3 units. EN: BME T, TU

E35 ESE 523 Information Theory
Discrete source and channel model, definition of information rate and channel capacity, coding theorems for sources and channels, encoding and decoding of data for transmission over noisy channels. Corequisite: ESE 520.
Credit 3 units. EN: BME T, TU

E35 ESE 524 Detection and Estimation Theory
Study of detection and estimation of signals in noise. Linear algebra, vector spaces, independence, projections. Data independence, factorization theorem and sufficient statistics. Neyman-Pearson and Bayes detection. Least squares, maximum-likelihood and maximum a posteriori estimation of signal parameters. Conjugate priors, recursive estimation, Wiener and Kalman filters. Prerequisite: ESE 520.
Credit 3 units. EN: BME T, TU

E35 ESE 527 Practicum in Data Analytics & Statistics
In this course, students will learn through hands-on experience the application of analytics to support data-driven decisions. Through lectures and the execution of a project (to be defined at the beginning of the semester), students will learn to use descriptive, predictive, and prescriptive analytics. Lectures will focus on presenting analytic topics relevant to the execution of the project, including analytic model development, data quality and data models, review of machine learning algorithms (unsupervised, supervised, and semi-supervised approaches), model validation, insights generation and results communication, and code review and code repository. Students are expected to demonstrate the application of these concepts through the execution of a one-semester project. Students can propose their own projects or choose from a list of projects made available by the lecturer. Projects should reflect real-world problems with a clear value proposition. Progress will be evaluated and graded periodically during the semester, and the course will include a final presentation open to the academic community. Prerequisites: ESE 520 (or Math 493 and 494), ESE 417 or CSE 417T, ESE 415, and declaration of the MS in DAS.
Credit 3 units. EN: BME T, TU

E35 ESE 531 Nano and Micro Photonics
This course focuses on fundamental theory, design, and applications of photonic materials and micro/nano photonic devices. It includes review and discussion of light-matter interactions in nano and micro scales, propagation of light in waveguides, nonlinear optical effect and optical properties of nano/micro structures, the device principles of waveguides, filters, photodetectors, modulators and lasers. Prerequisite: ESE 330.
Credit 3 units. EN: BME T, TU

E35 ESE 532 Introduction to Nano-Photonic Devices
Introduction to photon transport in nano-photonic devices. This course focuses on the following topics: light and photons, statistical properties of photon sources, temporal and spatial correlations, light-matter interactions, optical nonlinearity, atoms and quantum dots, single- and two-photon devices, optical devices, and applications of nano-photonic devices in quantum and classical computing and communication. Prerequisites: ESE 330 and Physics 217, or permission of instructor.
Credit 3 units. EN: BME T, TU

E35 ESE 5331 Nanophotonic Optical Media — From Metamaterials to Photonic Crystals and Beyond
The nanometer length scale holds a unique significance for optical engineering because it is home to the wavelengths of visible and infrared light. The behavior of a light wave is particularly sensitive to structural features formed at or below the scale of its wavelength and, as a consequence, nanophotonics encompasses many new and useful phenomena not found in macroscopic systems. In this course, we will explore the physics of light-matter coupling before using it as a guide to engineer new optical material properties via nanofabrication, with applications in computing, telecommunications, biomedical sensing, solar energy harvesting, robotics and more. Key topics covered in the course include Mie resonant dielectric antennas, plasmonic antennas, negative and zero refractive index metamaterials, chiral metamaterials, metasurface lenses and holograms, nonlinear and time dependent metasurfaces, Bragg mirrors, 3D photonic crystals, photonic crystal slab waveguides and cavities, guided mode resonators, photonic crystal lasers.
Credit 3 units.

E35 ESE 536 Introduction to Quantum Optics
This course covers the following topics: quantum mechanics for quantum optics, radiative transitions in atoms, lasers, photon statistics (photon counting, sub-/super-Poissionian photon statistics, bunching, anti-bunching, theory of photodetection, shot noise), entanglement, squeezed light, atom-photon interactions, cold atoms, abd atoms in cavities. If time permits, the following topics will be selectively covered: quantum computing, quantum cryptography, and teleportation. Prerequisites: ESE 330 and Physics 217 or Physics 421
Credit 3 units. EN: BME T, TU

E35 ESE 543 Control Systems Design by State Space Methods
Advanced design and analysis of control systems by state-space methods: classical control review, Laplace transforms, review of linear algebra (vector space, change of basis, diagonal and Jordan forms), linear dynamic systems (modes, stability, controllability, state feedback, observability, observers, canonical forms, output feedback, separation principle and decoupling), nonlinear dynamic systems (stability, Lyapunov methods). Frequency domain analysis of multivariable control systems. State space control system design methods: state feedback, observer feedback, pole placement, linear optimal control. Design exercises with CAD (computer-aided design) packages for engineering problems. Prerequisite: ESE 351 and ESE 441, or permission of instructor.
Credit 3 units. EN: BME T, TU

E35 ESE 544 Optimization and Optimal Control
Constrained and unconstrained optimization theory. Continuous time as well as discrete-time optimal control theory. Time-optimal control, bang-bang controls and the structure of the reachable set for linear problems. Dynamic programming, the Pontryagin maximum principle, the Hamiltonian-Jacobi-Bellman equation and the Riccati partial differential equation. Existence of classical and viscosity solutions. Application to time optimal control, regulator problems, calculus of variations, optimal filtering and specific problems of engineering interest. Prerequisites: ESE 551, ESE 552.
Credit 3 units. EN: BME T, TU

E35 ESE 545 Stochastic Control
Introduction to the theory of stochastic differential equations based on Wiener processes and Poisson counters, and an introduction to random fields. The formulation and solution of problems in nonlinear estimation theory. The Kalman-Bucy filter and nonlinear analogues. Identification theory. Adaptive systems. Applications. Prerequisites: ESE 520 and ESE 551.
Credit 3 units. EN: BME T, TU

E35 ESE 546 Dynamics & Control in Neuroscience & Brain Medicine
This course provides an introduction to systems engineering approaches to modeling, analysis and control of neuronal dynamics at multiple scales. A central motivation is the manipulation of neuronal activity for both scientific and medical applications using emerging neurotechnology and pharmacology. Emphasis is placed on dynamical systems and control theory, including bifurcation and stability analysis of single neuron models and population mean-field models. Synchronization properties of neuronal networks are covered, and methods for control of neuronal activity in both oscillatory and non-oscillatory dynamical regimes are developed. Statistical models for neuronal activity are also discussed. An overview of signal processing and data analysis methods for neuronal recording modalities is provided toward the development of closed-loop neuronal control paradigms. The final evaluation is based on a project or research survey. Prerequisites: ESE 553 (or equivalent); ESE 520 (or equivalent); ESE 351 (or equivalent).
Credit 3 units. EN: BME T, TU

E35 ESE 547 Robust and Adaptive Control
Graduate-level control system design methods for multi-input multi-output systems. Linear optimal-based methods in robust control, nonlinear model reference adaptive control. These design methods are currently used in most industry control system design problems. These methods are designed, analyzed and simulated using MATLAB. Linear control theory (review), robustness theory (Mu Analysis), optimal control and the robust servomechanism, H-infinity optimal control, robust output feedback controls, Kalman filter theory and design, linear quadratic gaussian with loop transfer recovery, the Loop Transfer Recovery method of Lavretsky, Mu synthesis, Lyapunov theory (review), LaSalle extensions, Barbalat's Lemma, model reference adaptive control, artificial neural networks, online parameter estimation, convergence and persistence of excitation. Prerequisite: ESE 543 or ESE 551 or equivalent.
Credit 3 units. EN: BME T, TU

E35 ESE 551 Linear Dynamic Systems I
Input-output and state-space description of linear dynamic systems. Solution of the state equations and the transition matrix. Controllability, observability, realizations, pole-assignment, observers and decoupling of linear dynamic systems. Prerequisite: ESE 351.
Credit 3 units. EN: BME T, TU

E35 ESE 552 Linear Dynamic Systems II
Least squares optimization problems. Riccati equation, terminal regulator and steady-state regulator. Introduction to filtering and stochastic control. Advanced theory of linear dynamic systems. Geometric approach to the structural synthesis of linear multivariable control systems. Disturbance decoupling, system invertibility and decoupling, extended decoupling and the internal model principle. Prerequisite: ESE 551.
Credit 3 units. EN: TU

E35 ESE 553 Nonlinear Dynamic Systems
State space and functional analysis approaches to nonlinear systems. Questions of existence, uniqueness and stability; Lyapunov and frequency-domain criteria; w-limits and invariance, center manifold theory and applications to stability, steady-state response and singular perturbations. Poincare-Bendixson theory, the van der Pol oscillator, and the Hopf Bifurcation theorem. Prerequisite: ESE 551.
Credit 3 units. EN: BME T, TU

E35 ESE 554 Advanced Nonlinear Dynamic Systems
Differentiable manifolds, vector fields, distributions on a manifold, Frobenius' theorem, Lie algebras. Controllability, observability of nonlinear systems, examined from the viewpoint of differential geometry. Transformation to normal forms. Exact linearization via feedback. Zero dynamics and related properties. Noninteracting control and disturbance decoupling. Controlled invariant distributions. Noninteracting control with internal stability. Prerequisites: ESE 553 and ESE 551.
Credit 3 units.

E35 ESE 557 Hybrid Dynamic Systems
Theory and analysis of hybrid dynamic systems, which is the class of systems whose state is composed by continuous-valued and discrete-valued variables. Discrete-event systems models and language descriptions. Models for hybrid systems. Conditions for existence and uniqueness. Stability and verification of hybrid systems. Optimal control of hybrid systems. Applications to cyber-physical systems and robotics. Prerequisite: ESE 551.
Credit 3 units. EN: BME T, TU

E35 ESE 559 Special Topics in Systems and Control
This course provides a rigorous introduction to recent developments in systems and controls. Focus is on the discussion of interdisciplinary applications of complex systems that motivate emerging topics in dynamics and control as well as state-of-the-art methods for addressing the control and computation problems involving these large-scale systems. Topics to be covered include the control of ensemble systems, pseudospectral approximation and high-dimensional optimization, the mathematics of networks, dynamic learning and topological data analysis, and applications to biology, neuroscience, brain medicine, quantum physics, and complex networks. Both model-based and data-driven approaches are introduced. Students learn about state-of-the-art research in the field, and they ultimately apply their knowledge to conduct a final project. Prerequisites: Math 429 or equivalent, ESE 415, ESE 551, ESE 553, and ESE 520.
Credit 3 units. EN: TU

E35 ESE 5591 Special Topics in Engineering and Neuroscience
Credit 2 units. EN: TU

E35 ESE 560 Computer Systems Architecture I
An exploration of the central issues in computer architecture: instruction set design, addressing and register set design, control unit design, memory hierarchies (cache and main memories, virtual memory), pipelining, instruction scheduling, and parallel systems. The course emphasizes understanding the performance implications of design choices, using architecture modeling and evaluation using simulation techniques. Prerequisites: CSE 361S and CSE 260M.
Same as E81 CSE 560M
Credit 3 units. EN: BME T, TU

E35 ESE 562 Analog Integrated Circuits
This course focuses on fundamental and advanced topics in analog and mixed-signal VLSI techniques. The first part of the course covers graduate level materials in the area of analog circuit synthesis and analysis. The second part of the course covers applications of the fundamental techniques for designing analog signal processors and data converters. Several practical aspects of mixed-signal design, simulation and testing are covered in this course. This is a project-oriented course and it is expected that the students apply the concepts learned in the course to design, simulate and explore different circuit topologies. Prerequisite: E35 232.
Credit 3 units.

E35 ESE 566A Modern System-on-Chip Design
The System-on-Chip (SoC) technology is at the core of most electronic systems: smartphones, wearable devices, autonomous robots and cars, and aerospace and medical electronics. In these SoCs, billions of transistors can be integrated on a single silicon chip containing various components, such as microprocessors, DSPs, hardware accelerators, memories, and I/O interfaces. Topics include SoC architectures, design tools, and methods as well as system-level trade-offs between performance, power consumption, energy efficiency, reliability, and programmability. Students will gain an insight into the early stages of the SoC design process by performing the tasks of developing functional specifications, applying partitions and map functions to hardware and/or software, and then evaluating and validating system performance. Assignments include hands-on design projects. This course is open to both graduate and senior undergraduate students. Prerequisite: ESE 461.
Credit 3 units. EN: BME T, TU

E35 ESE 567 Computer Systems Analysis
A comprehensive course on performance analysis techniques. The topics include common mistakes, selection of techniques and metrics, summarizing measured data, comparing systems using random data, simple linear regression models, other regression models, experimental designs, 2**k experimental designs, factorial designs with replication, fractional factorial designs, one factor experiments, two factor full factorial design w/o replications, two factor full factorial designs with replications, general full factorial designs, introduction to queueing theory, analysis of single queues, queueing networks, operational laws, mean-value analysis, time series analysis, heavy tailed distributions, self-similar processes, long-range dependence, random number generation, analysis of simulation results, and art of data presentation. Prerequisites: CSE 260M.
Same as E81 CSE 567M
Credit 3 units. EN: BME T, TU

E35 ESE 570 Coding Theory
Introduction to the algebra of finite fields. Linear block codes, cyclic codes, BCH and related codes for error detection and correction. Encoder and decoder circuits and algorithms. Spectral descriptions of codes and decoding algorithms. Code performances.
Credit 3 units. EN: TU

E35 ESE 571 Transmission Systems and Multiplexing
Transmission and multiplexing systems are essential to providing efficient point-to-point communication over distance. This course introduces the principles underlying modern analog and digital transmission and multiplexing systems and covers a variety of system examples.
Credit 3 units. EN: TU

E35 ESE 572 Signaling and Control in Communication Networks
The operation of modern communications networks is highly dependent on sophisticated control mechanisms that direct the flow of information through the network and oversee the allocation of resources to meet the communication demands of end users. This course covers the structure and operation of modern signaling systems and addresses the major design trade-offs that center on the competing demands of performance and service flexibility. Specific topics covered include protocols and algorithms for connection establishment and transformation, routing algorithms, overload and failure recovery and networking dimensioning. Case studies provide concrete examples and reveal the key design issues. Prerequisites: graduate standing and permission of instructor.
Credit 3 units. EN: BME T, TU

E35 ESE 575 Fiber-Optic Communications
Introduction to optical communications via glass-fiber media. Pulse-code modulation and digital transmission methods, coding laws, receivers, bit-error rates. Types and properties of optical fibers; attenuation, dispersion, modes, numerical aperture. Light-emitting diodes and semiconductor laser sources; device structure, speed, brightness, modes, electrical properties, optical and spectral characteristics. Prerequisites: ESE 330, ESE 336.
Credit 3 units. EN: BME T, TU

E35 ESE 582 Fundamentals and Applications of Modern Optical Imaging
Analysis, design, and application of modern optical imaging systems with emphasis on biological imaging. The first part of the course will focus on the physical principles underlying the operation of imaging systems and their mathematical models. Topics include ray optics (speed of light, refractive index, laws of reflection and refraction, plane surfaces, mirrors, lenses, aberrations), wave optics (amplitude and intensity, frequency and wavelength, superposition and interference, interferometry), Fourier optics (space-invariant linear systems, Huygens-Fresnel principle, angular spectrum, Fresnel diffraction, Fraunhofer diffraction, frequency analysis of imaging systems), and light-matter interaction (absorption, scattering, dispersion, fluorescence). The second part of the course will compare modern quantitative imaging technologies, including but not limited to digital holography, computational imaging, and super-resolution microscopy. Students will evaluate and critique recent optical imaging literature. Prerequisites: ESE 318 and ESE 319 (or their equivalents); ESE 330 or PHY 421 (or equivalent).
Credit 3 units. EN: TU

E35 ESE 584 Statistical Signal Processing for Sensor Arrays
Methods for signal processing and statistical inference for data acquired by an array of sensors, such as those found in radar, sonar and wireless communications systems. Multivariate statistical theory with emphasis on the complex multivariate normal distribution. Signal estimation and detection in noise with known statistics, signal estimation and detection in noise with unknown statistics, direction finding, spatial spectrum estimation, beam forming, parametric maximum-likelihood techniques. Subspace techniques, including MUSIC and ESPRIT. Performance analysis of various algorithms. Advanced topics may include structured covariance estimation, wide-band array processing, array calibration, array processing with polarization diversity, and space-time adaptive processing (STAP). Prerequisites: ESE 520, ESE 524, linear algebra, computer programming.
Credit 3 units. EN: TU

E35 ESE 585A Sparse Modeling for Imaging and Vision
Sparse modeling is at the heart of modern imaging, vision, and machine learning. It is a fascinating new area of research that seeks to develop highly effective data models. The core idea in sparse modeling theory is a novel redundant transform, where the number of transform coefficients is larger compared to the original data dimension. Together with redundancy comes an opportunity for seeking the sparsest possible representation or the one with the fewest non-zeros. This core idea leads to a series of beautiful theoretical and practical results with many applications, such as regression, prediction, restoration, extrapolation, compression, detection, and recognition. In this course, we will explore sparse modeling by covering theoretical as well as algorithmic aspects with applications in computational imaging and computer vision. Prerequisites: ESE 318, Math 233, Math 309, and Math 429 (or equivalents), as well as coding experience with MATLAB or Python.
Credit 3 units. EN: BME T, TU

E35 ESE 588 Quantitative Image Processing
Introduction to modeling, processing, manipulation and display of images. Application of two-dimensional linear systems to image processing. Two-dimensional sampling and transform methods. The eye and perception. Image restoration and reconstruction. Multiresolution processing, noise reduction and compression. Boundary detection and image segmentation. Case studies in image processing (examples: computer tomography and ultrasonic imaging). Prerequisites: ESE 326, ESE 482.
Credit 3 units. EN: BME T, TU

E35 ESE 589 Biological Imaging Technology
This class develops a fundamental understanding of the physics and mathematical methods that underlie biological imaging and critically examine case studies of seminal biological imaging technology literature. The physics section examines how electromagnetic and acoustic waves interact with tissues and cells, how waves can be used to image the biological structure and function, image formation methods, and diffraction limited imaging. The math section examines image decomposition using basis functions (e.g., Fourier transforms), synthesis of measurement data, image analysis for feature extraction, reduction of multidimensional imaging datasets, multivariate regression, and statistical image analysis. Original literature on electron, confocal and two photon microscopy, ultrasound, computed tomography, functional and structural magnetic resonance imaging and other emerging imaging technology are critiqued.
Credit 3 units. EN: BME T, TU

E35 ESE 590 Electrical & Systems Engineering Graduate Seminar
This satisfactory/unsatisfactory course is required for the master's, DSc, and PhD degrees in Electrical & Systems Engineering. A satisfactory grade is required for each semester of enrollment, and this is achieved by student attendance at regularly scheduled seminars. Master's students must attend at least three seminars per semester, except for first-year master's students, who must attend four. DSc and PhD students must attend at least five seminars per semester, except for first-year PhD students who must attend six. Part-time students are exempt except during their year of residency. Any student under continuing status is also exempt.

E35 ESE 591 Biomedical Optics I: Principles
This course covers the principles of optical photon transport in biological tissue. This course covers the principles and applications of optical photon transport in biological tissue. Topics include a brief introduction to biomedical optics, single-scatterer theories, Monte Carlo modeling of photon transport, convolution for broad-beam responses, radiative transfer equation, diffusion theory and applications, sensing of optical properties and spectroscopy, and photoacoustic imaging principles and applications. Prerequisite: Familiarity with Differential equations and partial differential equations
Same as E62 BME 591
Credit 3 units. EN: TU

E35 ESE 5931 Mathematics of Imaging Science
This course will expose students to a unified treatment of the mathematical properties of images and imaging. This will include an introduction to linear vector space theory, operator theory on Hilbert spaces, and concepts from applied functional analysis. Further, concepts from generalized functions, Fourier analysis, and radon transform will be discussed. These tools will be applied to conduct deterministic analyses of imaging systems that are described as continuous-to-continuous, continuous-to-discrete, and discrete-to-discrete mappings from object properties to image data. In addition, imaging systems will be analyzed in a statistical framework where stochastic models for objects and images will be introduced. Familiarity with Engineering-level mathematics, Calculus, Linear algebra, introduction to Fourier analysis is expected. Prerequisite: Senior standing or permission of instructor.
Same as E62 BME 570
Credit 3 units.

E35 ESE 5932 Computational Methods for Imaging Science
Inverse problems are ubiquitous in science and engineering, and they form the basis for modern imaging methods. This course will introduce students to the mathematical formulation of inverse problems and modern computational methods employed to solve them. Specific topics covered will include regularization theory, compressive sampling, variational calculus, and a survey of relevant numerical optimization methods. The application of these methods to tomographic imaging problems will be addressed in detail. Prerequisite: ESE 5931 or permission of instructor.
Credit 3 units. EN: BME T, TU

E35 ESE 5933 Theoretical Imaging Science
Imaging science encompasses the design and optimization of imaging systems to quantitatively measure information of interest. Imaging systems are important in many scientific and medical applications and may be designed for one specific application or for a range of applications. Performance is quantified for any given task through an understanding of the statistical model for the imaging data, the data processing algorithm used, and a measure of accuracy or error. Optimal processing is based on statistical decision theory and estimation theory; performance bounds include the receiver operating characteristic and Cramer-Rao bounds. Bayesian methods often lead to ideal observers. Extensions of methods from finite-dimensional spaces to function space are fundamental for many imaging applications. A variety of methods to assess image quality and resulting imaging system optimization are covered. Prerequisite: permission of instructor.
Credit 3 units. EN: TU

E35 ESE 5934 Practicum in Imaging Science
Students develop research results in computational imaging and write a conference paper on the results. This course involves the process of research project design and implementation in imaging science, participation in research teams, the development of milestones for a project, and the process of meeting expectations. The role of machine learning, computational methods, theoretical methods, datasets, and experiments in imaging science research are covered. Prerequisite: Permission of instructor.
Credit 3 units. EN: TU

E35 ESE 596 Seminar in Imaging Science and Engineering
This seminar course consists of a series of tutorial lectures on Imaging Science and Engineering with emphasis on applications of imaging technology. Students are exposed to a variety of imaging applications that vary depending on the semester, but may include multispectral remote sensing, astronomical imaging, microscopic imaging, ultrasound imaging and tomographic imaging. Guest lecturers come from several parts of the university. This course is required of all students in the Imaging Science and Engineering program; the only requirement is attendance. This course is graded pass/fail. Prerequisite: admission to Imaging Science and Engineering program. Same as CSE 596 (when offered) and BME 506.
Credit 1 unit.

E35 ESE 599 Master's Research
Prerequisite: Students must have the ESE Research/Independent Study Registration Form (PDF) (https://ese.wustl.edu/research/areas/Documents/Independent%20Study%20Form_1.pdf) approved by the department.
Credit variable, maximum 3 units.

E35 ESE 600 Doctoral Research
Credit variable, maximum 9 units.

E35 ESE 601 Research Rotation for ESE Doctoral Students
Doctoral students in Electrical and Systems Engineering are required to complete two rotations during their first year and may complete three rotations, with research mentors acceptable to the separtment. The rotations must be mutually agreeable to both the student and the faculty member. The grade will be assigned based on a written report from one of the rotations. The rotations allow students to sample different research projects and laboratory working environments and to enable the matching of doctoral students with the research mentors with whom they will carry out PhD dissertation research.
Credit 3 units.

Doctoral Degrees

PhD or DSc in Electrical Engineering or Systems Science & Mathematics

Students pursuing the Doctor of Philosophy (PhD) or Doctor of Science (DSc) degrees in Electrical Engineering or Systems Science & Mathematics must complete a minimum of 72 units of post-baccalaureate study consistent with the residency and other applicable requirements of the McKelvey School of Engineering. These 72 units must consist of at least 36 units of course work and at least 24 units of research, and they may include work done to satisfy the requirements of a master's degree in a related discipline. Up to 24 units for the PhD and 30 units for the DSc may be transferred to Washington University in St. Louis from another institution.

Below is a list of the steps needed to complete the requirements for a doctoral degree in the Department of Electrical & Systems Engineering. Each candidate for the degree must do the following:

- Complete at least 36 units of post-baccalaureate course work. Students are required to take at lease five courses from the Electrical & Systems Engineering department with a course number of 400 or higher.
- Complete the qualifying process (which includes a qualifying examination) and match with a research mentor before the second academic year of the program (PhD) or before the end of the third year of study (DSc).
- Pass an oral preliminary research examination, to be completed within two academic years of completing the qualifying process.
- Satisfy the general residency requirement for the McKelvey School of Engineering.
- Satisfy the general teaching requirement as specified by the department. (There is no teaching requirement for the DSc.)
- Write a doctoral dissertation that describes the results of original and creative research in a specialization within electrical engineering or systems science and mathematics.
- Pass a final oral examination in defense of the dissertation research.
- Take ESE 590 Electrical & Systems Engineering Graduate Seminar each semester (PhD) or during each semester of full-time study (DSc).

Master of Science in Electrical Engineering (MSEE)

Either a thesis option or a course option may be selected. The special requirements for these options are as follows:

Course Option

The Master of Science in Electrical Engineering is an academic master's degree designed mainly for both full-time and part-time students interested in proceeding to the departmental full-time doctoral program and/or an industrial career. Under the course option, students may not take ESE 599 Master's Research. With faculty permission, they may take up to 3 units of graduate-level independent study.

Thesis Option

This option is intended for those pursuing full-time study and engaged in research projects. Candidates for this degree must complete a minimum of 24 units of course instruction and 6 units of thesis research (ESE 599); 3 of these units of thesis research may be applied toward the 15 core electrical engineering units required for the MSEE program. Any of these 6 units of thesis research may be applied as electives for the MSEE, MSSSM, and MSDAS programs. The student must write a master's thesis and defend it in an oral examination.

Degree Requirements

Students pursuing the degree Master of Science in Electrical Engineering (MSEE) must complete a minimum of 30 units of study consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering and subject to the following departmental requirements:

- A minimum of 15 of these units must be selected from the following list of core electrical engineering subjects taught by the Department of Electrical & Systems Engineering (ESE)

Code	Title	Units
ESE 415, 513	Optimization category	
ESE 520-529	Applied probability category	
ESE 530-539	Applied physics and electronics category	
ESE 540-549	Control category	
ESE 550-559, ESE 5590-5599	Systems category	
ESE 560-569	Computer engineering category	
ESE 570-579	Communications category	
ESE 580-589, ESE 591-596, ESE 5931-5933	Signal and image processing category	
ESE 599	Master's Research (thesis option only)	

- The remaining courses in the program may be selected from senior or graduate-level courses in ESE or elsewhere in the university that are approved by the department. Please consult the ESE departmental website (https://ese.wustl.edu/graduate/degreeprograms/Pages/ms-electrical-engineering.aspx) for a list of allowable electives.
- At least 15 units of the 30 total units applied toward the MSEE degree must be in ESE courses which, if cross-listed, have ESE as the home department.
- A maximum of 6 credits may be transferred from another institution and applied toward the master's degree. Regardless of the subject or level, all transfer courses are treated as electives and do not count toward the core requirements for the degree.
- ESE 590 Electrical & Systems Engineering Graduate Seminar must be taken by full-time graduate students each semester. This course is taken with the unsatisfactory/satisfactory grade option.
- The degree program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.
- Students must obtain a cumulative grade-point average of at least 3.0 out of a possible 4.0 overall for courses applied toward the degree. Courses that apply for the degree must be taken with the credit/letter grade option.

Master of Science in Systems Science & Mathematics (MSSSM)

Either a thesis option or a course option may be selected. The special requirements for these options are as follows:

Course Option

The Master of Science in Systems Science & Mathematics (MSSSM) is an academic master's degree that requires the completion of 30 credit units. It is designed for both full-time and part-time students interested in proceeding to the departmental full-time doctoral program and/or an industrial career. Under the course option, students may not take ESE 599 Master's Research. With faculty permission, they may take up to 3 units of graduate-level independent study.

Thesis Option

This option is intended for those pursuing full-time study and engaged in research projects. Candidates for this degree must complete a minimum of 24 credit units of course instruction and 6 credit units of thesis research (ESE 599); 3 of these units of thesis research may be applied toward the 15 core electrical engineering units required for the MSEE program. Any of these 6 units of thesis research may be applied as electives for the MSEE, MSSSM, and MSDAS programs. The student must write a master's thesis and defend it in an oral examination.

Degree Requirements

- Required courses (15 units) for the MS degree include the following:

Code	Title	Units
ESE 551	Linear Dynamic Systems I	3
ESE 553	Nonlinear Dynamic Systems	3
ESE 520	Probability and Stochastic Processes	3
ESE 415	Optimization *	3
and one course chosen from the following:		
ESE 524	Detection and Estimation Theory	3
or ESE 544	Optimization and Optimal Control	
or ESE 545	Stochastic Control	
or ESE 557	Hybrid Dynamic Systems	
Total Units		**15**

* ESE 513 may be substituted.

- The remaining courses in the program may be selected from senior or graduate-level courses in ESE or elsewhere in the university that are approved by the department. Please consult the ESE departmental website (https://ese.wustl.edu/graduate/degreeprograms/Pages/ms-systems-science-mathematics.aspx) for a list of allowable electives.

- A maximum of 6 units may be transferred from another institution and applied toward the master's degree.
- ESE 590 Electrical & Systems Engineering Graduate Seminar must be taken by full-time graduate students each semester. This course is taken with an unsatisfactory/satisfactory grade option.
- The degree program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.
- Students must obtain a cumulative grade-point average of at least 3.0 out of a possible 4.0 overall for courses applied toward the degree. Courses that apply toward the degree must be taken with the credit/letter grade option.

Master of Science in Engineering Data Analytics and Statistics (MSDAS)

Either a thesis option or a course option may be selected. The special requirements for these options are as follows:

Course Option

The Master of Science in Engineering Data Analytics and Statistics is an academic master's degree designed mainly for both full-time and part-time students interested in proceeding to the departmental full-time doctoral program and/or an industrial career. Under the course option, students may not take ESE 599 Master's Research. With faculty permission, they may take up to 3 units of graduate-level independent study.

Thesis Option

This option is intended for those pursuing full-time study and engaged in research projects. Candidates for this degree must complete a minimum of 24 units of course instruction and 6 units of thesis research (ESE 599); 3 of these units of thesis research may be applied toward the 15 core electrical engineering units required for the MSEE program. Any of these 6 units of thesis research may be applied as electives for the MSEE, MSSSM, and MSDAS programs. The student must write a master's thesis and defend it in an oral examination.

Degree Requirements

The MS in Engineering Data Analytics and Statistics (MSDAS) degree requires 30 units.

- Required courses (15 units) for the MS degree include the following:

Code	Title	Units
ESE 417	Introduction to Machine Learning and Pattern Classification	3
or CSE 417T	Introduction to Machine Learning	
or CSE 517A	Machine Learning	
ESE 415	Optimization	3
or ESE 513	Large-Scale Optimization for Data Science	
ESE 520	Probability and Stochastic Processes	3
ESE 524	Detection and Estimation Theory	3
ESE 527	Practicum in Data Analytics & Statistics	3
Total Units		**15**

Electives

- Please consult the ESE departmental website (https://ese.wustl.edu/academics/graduate-programs/masters-and-certificates/MS-in-Data-Analytics-Statistics.html) for a list of allowable electives.

- ESE 590 Electrical & Systems Engineering Graduate Seminar must be taken by full-time graduate students each semester. This course is taken with the unsatisfactory/satisfactory grade option.
- A maximum of 6 units may be transferred from another institution and applied toward the master's degree.
- The degree program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.
- Students must obtain a cumulative grade-point average of at least 3.0 out of a possible 4.0 overall for courses applied toward the degree. Courses that apply toward the degree must be taken with the credit/letter grade option.

Master of Science (MS) in Computer Engineering

The Master of Science (MS) in Computer Engineering is best suited for students who are looking to focus on computer engineering (hardware) aspects. The MS in Computer Engineering program can be a pure course option program, or it can incorporate either a project or a thesis. If appropriate research experiences are included in the degree option, this can also lead toward future doctoral studies. All students in the MS in Computer Engineering program must have previously completed (as documented by their undergraduate transcript), successfully test to place out of, or complete at the start of their program the following courses: CSE 501N Introduction to Computer Science and CSE 505N Introduction to Digital Logic and Computer Design (or equivalent courses offered at other institutions).

The Master of Science in Computer Engineering degree is jointly administered by the Department of Computer Science and Engineering and the Department of Electrical and Systems Engineering

Course Option

This option requires 30 units of graduate credit. Students must also follow the general degree requirements listed below.

Thesis/Project Option

The thesis and project options require 24 units of graduate credit in addition to 6 units of either thesis or project courses (CSE/ESE 599 or CSE 598, respectively). Students pursuing the project option may opt to take 27 units of graduate courses and only 3 units of CSE 598, with advisor approval. Students must also follow the general degree requirements listed below.

General Degree Requirements

- 18 of the 30 units must be from the designated graduate-level Computer Engineering courses. Please visit our MS in Computer Engineering website (https://cse.wustl.edu/graduate/programs/Pages/ms-in-computer-engineering.aspx) for a comprehensive list.
- Up to 12 units may be taken from outside the two departments. Such approval will be contingent on the credits being for suitably technical graduate-level content. To count more than 6 units from outside the CSE or ESE department, an appropriate justification for the additional increment must be provided by the advisor and student. Program approval will be evaluated with increasing stringency for each additional increment.
- Up to 12 units of 400-level courses can count for graduate credit.
- None of of the 30 units may be taken as independent study (i.e., CSE 400, CSE 500, ESE 400, or ESE 500).
- CSE courses with an "N" designation do not count toward the master's degree.
- All 30 units required for the degree must be taken for a grade (i.e., not pass/fail), and the grade received in each course must be C- or better.
- Per McKelvey School of Engineering guidelines, students must maintain a grade-point average of at least 2.70.

Certificate in Controls

Requirements

The requirements for the Certificate in Controls include the following:

- Acceptance into the program
- Completion of four courses (12 units) approved by the program director, with a minimum grade-point average of 3.0
- Completion of requirements for a graduate degree in the student's home department

Required Courses:

Code	Title	Units
ESE 520	Probability and Stochastic Processes	3
ESE 551	Linear Dynamic Systems I	3
ESE 553	Nonlinear Dynamic Systems	3

One of the following courses:

Code	Title	Units
ESE 415	Optimization	3
ESE 425	Random Processes and Kalman Filtering	3
ESE 543	Control Systems Design by State Space Methods	3
ESE 547	Robust and Adaptive Control	3

- The program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.
- Students must obtain a cumulative GPA of at least 3.0 out of a possible 4.0 overall for courses applied toward the degree. Courses that apply toward the degree must be taken with the credit/letter grade option.

Certificate in Imaging Science & Engineering (IS&E)

Washington University has been a leader in imaging science research for more than four decades, with many new medical imaging modalities, advanced applications in planetary science, and fundamental theories having been developed here. The Imaging Sciences Pathway (https://sites.wustl.edu/imagingsciences/) in the Division of Biology and Biological Sciences in Arts & Sciences is jointly administered with the McKelvey School of Engineering, with students pursuing degrees in departments across the university. The Imaging Science & Engineering (IS&E) certificate program complements the Imaging Sciences Pathway for students in the departments of Electrical & Systems Engineering, Biomedical Engineering, Computer Science & Engineering, Mechanical Engineering & Materials Science, Chemistry, Physics, and the Division of Biology and Biological Sciences. Each department has its own requirements, but all include the IS&E seminar. The program is flexible, so students are encouraged to appeal to the program director to identify individualized programs.

The IS&E certificate program is built on the strengths of imaging science throughout the university. This multidisciplinary program is constructed to expose students to the breadth of imaging research activities at Washington University. There has been an explosion of both increased bandwidth of existing imaging systems and new sensing modalities. The increase in bandwidth from sensors drives innovations in computing, image reconstruction and image understanding. New sensing modalities present unique opportunities for young researchers to make fundamental contributions.

Medical imaging continues to comprise the largest set of applications at Washington University. The resolution of modern whole-body imaging sensors has revolutionized medicine. The development of new portable imaging modalities broadens the impact by lowering cost. Imaging science includes understanding of the underlying physical, biological and chemical processes that yield signals of interest. Microscopes, visible/infrared cameras, magnetic resonance, X-ray, ultrasound and nuclear sensors provide the data used for imaging or inferring underlying processes. Imaging supports clinical diagnosis, radiation oncology, and molecular and neural imaging.

Imaging supports advances in earth and planetary science, enabling discovery from rovers on Mars, characterizing surface properties from satellites, and inferring internal phenomena in planetary objects. Modern understanding of materials science is driven in part by new imaging methods. New imaging systems for plant science seek better characterization of their biological systems.

Data rates from imaging systems demand efficient processing, manipulation and representation. In modern imaging systems, computing and sensing often must be jointly optimized. Inference is typically based on searching for meaningful patterns in the data, along with the relative contributions of those patterns.

For more information, please refer to the Department of Electrical & Systems Engineering website (http://ese.wustl.edu/) or contact the department directly.

Entering and Completing the Program

Graduate students in participating departments may apply for admission to the IS&E program. Admission requires graduate standing in a participating department, a demonstrated interest in aspects of imaging, and approval of the program director.

Upon being awarded a graduate degree by their home department and completing certain requirements of the program, students are awarded a certificate indicating their successful participation in the IS&E program in addition to having completion of the certificate program posted on their official transcript. The requirements for receiving a certificate are acceptance into the IS&E program, completion of four imaging courses approved by the program director, completion of the requirements for a graduate degree in the student's home department, and participation in the IS&E seminar required for all students in the IS&E program.

Seminars by faculty in imaging science, others at Washington University, and experts from outside the university convey new developments and directions in the field of imaging science and its applications. These seminars also provide the opportunity for interactions among those involved in the program.

Courses of Instruction

Fundamentals underlying imaging science and engineering and the application of these fundamentals to contemporary problems of importance form the theme of the program. Relevant courses come from across the university. The program is flexible, allowing students — in consultation with their advisors and the program director — to design a program that is best for them. Below are representative courses that students in the program take.

Required Seminar

Code	Title	Units
ESE 596	Seminar in Imaging Science and Engineering	
or BME 506	Seminar in Imaging Science and Engineering	
or Physics 596	Research	

Courses in the Imaging Sciences Pathway in the Division of Biology & Biological Sciences

Code	Title	Units
BME 530A	Molecular Cell Biology for Engineers	3
BME 589	Biological Imaging Technology	3
or ESE 589	Biological Imaging Technology	
Biol 5068	Fundamentals of Molecular Cell Biology	4
Biol 5146	Principles and Applications of Biological Imaging	3
Biol 5147	Contrast Agents for Biological Imaging	3
or Chem 5147	Contrast Agents for Biological Imaging	

Courses in Electrical & Systems Engineering

Code	Title	Units
ESE 438	Applied Optics	3
ESE 520	Probability and Stochastic Processes	3
ESE 524	Detection and Estimation Theory	3
ESE 582	Fundamentals and Applications of Modern Optical Imaging	3
ESE 589	Biological Imaging Technology	3
ESE 591	Biomedical Optics I: Principles	3
ESE 5931	Mathematics of Imaging Science	3
ESE 5932	Computational Methods for Imaging Science	3
ESE 5933	Theoretical Imaging Science	3
ESE 5934	Practicum in Imaging Science	3
ESE 596	Seminar in Imaging Science and Engineering (required)	1

Courses in Computer Science & Engineering

Code	Title	Units
CSE 517A	Machine Learning	3
CSE 546T	Computational Geometry	3
CSE 554A	Geometric Computing for Biomedicine	3
CSE 555A	Computational Photography	3
CSE 559A	Computer Vision	3

Courses in Biomedical Imaging

Code	Title	Units
BME 494	Ultrasound Imaging	3
BME 506	Seminar in Imaging Science and Engineering (required)	1
BME 530A	Molecular Cell Biology for Engineers	3
BME 570	Mathematics of Imaging Science	3

BME 5820	Fundamentals and Applications of Modern Optical Imaging	3
BME 589	Biological Imaging Technology	3
BME 591	Biomedical Optics I: Principles	3
BME 592	Biomedical Optics II: Imaging	3
BME 594	Ultrasound Imaging	3

Courses in Chemistry, Physics, and Psychology

Code	Title	Units
Chem 435	Nuclear and Radiochemistry Lab	3
Chem 436	Introduction to the Atomic Nucleus	3
Chem 576	Magnetic Resonance	3
Chem 5762	Electron Spin Resonance	3
Physics 534	Magnetic Resonance	3
Physics 589	Selected Topics in Physics I	3
Physics 590.1	Seminar: Physics of Ultrasonic Imaging in Cardiovascular Medicine	3
Psych 4450	Functional Neuroimaging Methods	3

Website: https://ese.wustl.edu/academics/graduate-programs/masters-and-certificates/Graduate-Certificate.html

Certificate in Quantum Engineering

Degree Requirements

The Certificate in Quantum Engineering requires the student to obtain a graduate degree at Washington University and the completion of the following two requirements:

- At least two courses must be from the Required Courses list.
- At least one of the electives needs to be a 5xx-level course.
- Units required: 12

Required Courses:

Code	Title	Units
ESE 4301	Quantum Mechanics for Engineers	3
ESE 429	Basic Principles of Quantum Optics and Quantum Information	3
or ESE 536	Introduction to Quantum Optics	
ESE 431	Introduction to Quantum Electronics	3
CSE 468T	Introduction to Quantum Computing	3

Program Electives:

Code	Title	Units
ESE 436	Semiconductor Devices	3
ESE 439	Introduction to Quantum Communications	3
ESE 532	Introduction to Nano-Photonic Devices	3
ESE 582/BME 5820	Fundamentals and Applications of Modern Optical Imaging	3
Chem 401	Physical Chemistry I	3
Chem 500	Independent Work	3
Chem 533	Time-Dependent Quantum Mechanics & Spectroscopy	3
Chem 543	Physical Properties of Quantum Nanostructures	3
Physics 472	Solid State Physics	3
Physics 589	Selected Topics in Physics I	3
Math 528	Topics in Functional Analysis II	3

- The program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.
- Students must obtain a cumulative grade-point average of at least 3.0 out of a possible 4.0 overall for courses applied toward the degree. Courses that apply toward the degree must be taken with the credit/letter grade option.

Energy, Environmental & Chemical Engineering

The Department of Energy, Environmental & Chemical Engineering (EECE) provides integrated and multidisciplinary programs of scientific education in cutting-edge areas, including the **PhD in Energy, Environmental & Chemical Engineering**. The research and educational activities of the department are organized into four clusters: aerosol science and engineering; engineered aquatic processes; multiscale and electrochemical engineering; and synthetic biology and bioproduct engineering. These overlapping clusters address education and research in four thematic areas: energy; environmental engineering science; advanced materials; and sustainable technology for public health and international development. In addition to the core faculty in the department, faculty in the schools of Medicine, Arts & Sciences, Business, Law, and Social Work collaborate to provide students with a holistic education and to address topical problems of interest.

Three master's programs are offered through the department: **Master of Science in Energy, Environmental & Chemical Engineering (MS), Master of Engineering in Energy, Environmental & Chemical Engineering (MEng)** and **Master of Engineering in Energy, Environmental & Chemical Engineering/Master of Business Administration (MEng/MBA)**. The MS degree is a research-focused master's program for students interested in studying environmental engineering, energy systems and chemical engineering. The MEng degree provides students with critical scientific and engineering skill sets; leadership training for management, economics, and policy decision making; and the opportunity to specialize in one of five pathways. The MEng/MBA is a dual degree between the McKelvey School of Engineering and the Olin Business School that provides engineering and business approaches to issues of sustainability, energy, the environment and corporate social responsibility. Interested students must apply and be accepted to both programs before admission is provided to the MEng/MBA dual-degree program.

The department is a key participant in the university's Energy, Environment & Sustainability (http://sustainability.wustl.edu/) initiative, and it supports both the International Center for Energy, Environment and Sustainability (InCEES) (http://incees.wustl.edu/) and the McDonnell Academy Global Energy and Environment Partnership (MAGEEP). Major externally funded research centers in the department include the Consortium for Clean Coal Utilization (http://cleancoal.wustl.edu/), the Nano Research Facility (NRF) and Jens Environmental Molecular and Nanoscale Analysis Laboratory (Jens Lab) (https://research.wustl.edu/core-facilities/nano-research-facility/), and the Center for Aerosol Science and Engineering (CASE) (https://aerosols.wustl.edu/).

Phone:	314-935-5548
Website:	https://eece.wustl.edu/academics/graduate-programs/index.html

Faculty

Department Chair and Professor

Joshua Yuan (https://engineering.wustl.edu/faculty/Joshua-Yuan.html)
Lucy & Stanley Lopata Professor
PhD, University of Tennessee
Design-based engineering to address challenges in energy, the environment and health

Endowed Professors

Richard L. Axelbaum (https://engineering.wustl.edu/faculty/Richard-Axelbaum.html)
The Stifel & Quinette Jens Professor of Environmental Engineering Science
PhD, University of California, Davis
Combustion, advanced energy systems, clean coal, aerosols, nanoparticle synthesis, rechargeable battery materials, thermal science

Daniel E. Giammar (https://engineering.wustl.edu/faculty/Daniel-Giammar.html)
Walter E. Browne Professor of Environmental Engineering
PhD, California Institute of Technology
Aquatic chemistry, environmental engineering, water quality, water treatment

Randall Martin (https://engineering.wustl.edu/faculty/Randall-Martin.html)
Raymond R. Tucker Distinguished Professor
PhD, Harvard University
Characterizing atmospheric composition to inform effective policies surrounding major environmental and public health challenges ranging from air quality to climate change

Vijay Ramani (https://engineering.wustl.edu/faculty/Vijay-Ramani.html)
Vice Provost for Graduate Education and International Affairs
Roma B. and Raymond H. Wittcoff Distinguished University Professor
PhD, University of Connecticut
Electrochemical engineering, energy conversion

Jay R. Turner (https://engineering.wustl.edu/faculty/Jay-Turner.html)
Head of the Division of Engineering Education
Vice Dean for Education
James McKelvey Professor of Engineering Education
DSc, Washington University
Air quality planning and management, aerosol science and engineering, green engineering

Professors

Zhen (Jason) He (https://engineering.wustl.edu/faculty/Zhen-Jason-He.html)
Director of Graduate Studies
PhD, Washington University
Environmental biotechnology, bioenergy production, biological wastewater treatment, resource recovery, bioelectrochemical systems, sustainable desalination technology, anaerobic digestion, forward osmosis, membrane bioreactors

Young-Shin Jun (https://engineering.wustl.edu/faculty/Young-Shin-Jun.html)
PhD, Harvard University
Aquatic processes, molecular issues in chemical kinetics, environmental chemistry, surface/physical chemistry, environmental engineering, biogeochemistry, nanotechnology

Xinhua Liang
PhD, University of Colorado Boulder
Gas-phase synthesis, surface science and catalysis, nanostructured films and devices, energy and environmental applications

Yinjie Tang (https://engineering.wustl.edu/faculty/Yinjie-Tang.html)
PhD, University of Washington
Metabolic modeling, fermentation engineering, algal bioprocesses

Jian Wang (https://engineering.wustl.edu/faculty/Jian-Wang.html)
Director of the Center for Aerosol Science and Engineering (CASE)
PhD, California Institute of Technology
Aerosol properties and processes, nucleation and new particle formation, aerosols in the marine environment, effects of aerosols on cloud microphysical properties and macrophysical structure

Fuzhong Zhang (https://engineering.wustl.edu/faculty/Fuzhong-Zhang.html)
PhD, University of Toronto
Metabolic engineering, protein engineering, synthetic and chemical biology

Associate Professors

Rajan Chakrabarty (https://engineering.wustl.edu/faculty/Rajan-Chakrabarty.html)
Harold D. Jolley Career Development Associate Professor
PhD, University of Nevada, Reno
Characterizing the radiative properties of carbonaceous aerosols in the atmosphere, researching gas-phase aggregation of aerosols in cluster-dense conditions

Marcus Foston (https://engineering.wustl.edu/faculty/Marcus-Foston.html)
Director of Diversity Initiatives
PhD, Georgia Institute of Technology
Utilization of biomass resources for fuel and chemical production, renewable synthetic polymers, development of advanced aerosol instruments

Tae Seok Moon (https://engineering.wustl.edu/faculty/Tae-Seok-Moon.html)
PhD, Massachusetts Institute of Technology
Metabolic engineering, synthetic biology

Elijah Thimsen (https://engineering.wustl.edu/faculty/Elijah-Thimsen.html)
PhD, Washington University in St. Louis
Gas-phase synthesis of inorganic nanomaterials for energy applications, novel plasma synthesis approaches

Assistant Professors

Peng Bai (https://engineering.wustl.edu/faculty/Peng-Bai.html)
PhD, Tsinghua University, China
Develop next-generation batteries; probe the in situ electrochemical dynamics of miniature electrodes down to nanoscales; capture the heterogeneous and stochastic nature of advanced electrodes; identify the theoretical pathways and boundaries for the rational design of materials, electrodes, and batteries through physics-based mathematical modeling and simulation

Jenna Ditto
PhD, Yale University
Chemical composition of indoor and outdoor air, indoor air chemistry, health impacts of air pollution exposure

Fangqiong Ling (https://engineering.wustl.edu/faculty/Fangqiong-Ling.html)
PhD, University of Illinois at Urbana-Champaign
Microbial ecosystem analysis and modelling, process modelling, machine learning, NextGen sequencing bioinformatics, environmental microbiology, bioreactor design

Kimberly M. Parker (https://engineering.wustl.edu/faculty/Kimberly-Parker.html)
PhD, Stanford University
Investigation of environmental organic chemistry in natural and engineered systems

Lu Xu
PhD, Georgia Institute of Technology
Air quality, climate change, atmospheric chemistry

Research Assistant Professor

Benjamin Kumfer (https://engineering.wustl.edu/faculty/Benjamin-Kumfer.html)
DSc, Washington University
Advanced coal technologies, biomass combustion, aerosol processes and health effects of combustion-generated particles

Senior Lecturers

Janie Brennan (https://engineering.wustl.edu/faculty/Janie-Brennan.html)
Director of Undergraduate Studies
PhD, Purdue University
Chemical engineering education, biomaterials

Raymond Ehrhard (https://engineering.wustl.edu/faculty/Ray-Ehrhard.html)
BS, Missouri University of Science and Technology
Water and wastewater treatment technologies, process energy management

Trent Silbaugh (https://engineering.wustl.edu/faculty/Trent-Silbaugh.html)
PhD, University of Washington
Chemical engineering education, catalysis, carbon capture and conversion

Kristen Wyckoff
PhD, University of Tennessee
Environmental engineering education, stormwater runoff, environmental microbiology

Lecturer

Kurt Russell
PhD, Purdue University
Chemical engineering education, catalysis

Affiliated Faculty

Gary Moore
Senior Lecturer for the Joint Engineering Program
MS, Missouri University of Science and Technology
Environmental management

Adjunct Faculty

Keith Tomazi
PhD, University of Missouri-Rolla
Process development engineering

Grigoriy Yablonsky
PhD, Boreskov Institute of Catalysis
Chemical reaction engineering and heterogeneous catalysis

Emeritus Professor

Milorad P. Dudukovic
Laura and William Jens Emeritus Professor
PhD, Illinois Institute of Technology
Chemical reaction engineering, multiphase reactors, visualization of multiphase flows, tracer methods, environmentally benign processing

Degree Requirements

Please visit the following pages for information about the degrees offered:

- PhD in Energy, Environmental & Chemical Engineering (EECE) (p. 73)
- Master of Science (MS) in Energy, Environmental & Chemical Engineering (EECE) (p. 73)
- Master of Engineering (MEng) in Energy, Environmental & Chemical Engineering (EECE) (p. 73)
- Combined Master of Engineering/Master of Business Administration (MEng/MBA) (given jointly with Olin Business School) (p. 74)

Courses

Visit online course listings to view semester offerings for E44 EECE (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E44&crslvl=5:8).

E44 EECE 500 Independent Study
Independent investigation on topic of special interest. Interested students are encouraged to approach and engage faculty to develop a topic of interest. A form declaring the agreement must be filed in the departmental office. Petitions are generally considered in the semester preceding the independent study experience. Prerequisite: graduate-level standing.
Credit variable, maximum 9 units.

E44 EECE 501 Transport Phenomena in EECE
The aim of the course is for students to develop skills in applying principles of momentum, heat and mass transport in an unified manner to problems encountered in the areas of energy, environmental and chemical processes. A systems approach will be followed so that the general principles can be grasped and the skills to develop mathematical models of seemingly different processes will be emphasized. This provides the students with a general tool which they can apply later in their chosen field of research. Prerequisite: Graduate standing or permission of instructor.
Credit 3 units.

E44 EECE 502 Advanced Thermodynamics in EECE
The objective of this course is to understand classical thermodynamics at a deeper level then is reached during typical undergraduate work. Emphasis will be placed on solving problems relevant to chemical engineering materials science. Prerequisite: E44 EECE 205 or graduate level standing or permission of instructor
Credit 3 units.

E44 EECE 504 Aerosol Science and Technology
Fundamental properties of particulate systems - physics of aerosols, size distributions, mechanics and transport of particles: diffusion, inertia, external force fields. Visibility and light scattering. Aerosol dynamics - coagulation, nucleation, condensation. Applications to engineered systems: Nanoparticle synthesis, atmospheric aerosols, combustion aerosols, pharmaceutical aerosols. Prerequisites: E44 EECE 301, E35 ESE 318 and E35 ESE 319 or graduate level standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 505 Aquatic Chemistry
Aquatic chemistry governs aspects of the biogeochemical cycling of trace metals and nutrients, contaminant fate and transport, and the performance of water and wastewater treatment processes. This course examines chemical reactions relevant to natural and engineered aquatic systems. A quantitative approach emphasizes the solution of chemical equilibrium and kinetics problems. Topics covered include chemical equilibrium and kinetics, acid-base equilibria and alkalinity, dissolution and precipitation of solids, complexation of metals, oxidation-reduction processes, and reactions on solid surfaces. A primary objective of the course is to be able to formulate and solve chemical equilibrium problems for complex environmental systems. In addition to solving problems manually to develop chemical intuition regarding aquatic systems, software applications for solving chemical equilibrium problems are also introduced. Prerequisite: Senior or graduate-level standing or permission of instructor. Students enrolling in this course should have a knowledge of general chemistry.
Credit 3 units. EN: BME T, TU

E44 EECE 506 Bioprocess Engineering I: Fundamentals & Applications
The course covers the fundamentals and provides the basic knowledge needed to understand and analyze processes in biotechnology in order to design, develop and operate them efficiently and economically. This knowledge is applied to understand various applications and bioprocesses, such as formation of desirable bio and chemical materials and products, production of bioenergy, food processing and waste treatment. The main objective of the course is to introduce the essential concepts and applications of bioprocessing to students of diverse backgrounds. An additional project is required to obtain graduate credit. Prerequisites: L41 Biol 2960 or E44 EECE 306 or graduate level standing permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 507 Kinetics and Reaction Engineering Principles
The course is aimed at a modern multiscale treatment of kinetics of chemical and biochemical reactions and application of these fundamentals to analyze and design reactors. Application of reaction engineering principles in the areas related to energy generation, pollution prevention, chemical and biochemical processes will be studied and illustrated with case studies and computer models. Description of the role of mass and heat transport in reacting systems is also provided with numerous examples. Prerequisites: E44 EECE 503 or E35 ESE 318 and E35 ESE 319; E44 EECE 403; or permission of instructor.
Credit 3 units.

E44 EECE 508 Research Rotation
First-year doctoral students in EECE should undertake this rotation as a requirement prior to choosing a permanent research adviser. The rotation will require the student to work under the guidance of a faculty member.

E44 EECE 509 Seminar in Energy, Environmental, and Chemical Engineering
All graduate students in EECE should attend the departmental seminar series to gain exposure in various diverse fields of research. Students are also expected to participate in journal clubs and other discussion formats to discuss topical research areas. This course is required of all graduate students every semester of residency in the program.
Credit 1 unit.

E44 EECE 510 Advanced Topics in Aerosol Science & Engineering
This course will be focused on the discussion of advanced topics in aerosol science and engineering and their applications in a variety of fields, including materials science, chemical engineering, mechanical engineering, and environmental engineering. Prerequisite: EECE 504 or permission of instructor
Credit 3 units. EN: BME T, TU

E44 EECE 512 Combustion Phenomena
This course provides an introduction to fundamental aspects of combustion phenomena, including relevant thermochemistry, fluid mechanics, and transport processes as well as the interactions among them. Emphasis is on elucidation of the physico-chemical processes, problem formulation and analytic techniques. Topics covered include non-premixed and premixed flames, deflagrations and detonations, particle combustion, flame extinction, flame synthesis, pollutant formation and methods of remediation. Contemporary topics associated with combustion are discussed throughout. Prerequisite: Senior or graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 514 Atmospheric Science and Climate
This course will cover current research topics in atmospheric chemistry and climate change. Topics include atmospheric composition, chemistry, transport, dynamics, radiation, greenhouse gases, natural and anthropogenic primary pollution sources and secondary aerosol production, and measurement techniques. Focus will be placed on how our atmosphere and climate are altered in a world of changing energy production and land use. Suggested prerequisites: one year of general chemistry (Chem 111A-112A or 105-106) and one year of general physics (191/191L-191/192L). Prerequisites: Junior, senior or graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 516 Measurement Techniques for Particle Characterization
The purpose of this course is to introduce students to the principles and techniques of particle measurement and characterization. Practical applications of particle technology include air pollution measurement, clean manufacturing of semiconductors, air filtration, indoor air quality, particulate emission from combustion sources, and so on. The course will focus on the following: (1) integral moment measurement techniques; (2) particle sizing and size distribution measuring techniques; and (3) particle composition measurement techniques. Related issues such as particle sampling and transportation, instrument calibration, and particle standards will also be covered. Prerequisite: E44 EECE 504, graduate standing, or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 520 Special Topics: Plasma Science and Engineering
This course will focus on a select set of fundamentals and technology related to nonequilibrium plasmas, which are partially ionized gases. Fundamental discussion will focus on the set of state variables that define the plasma and the interaction of the plasma with surfaces, suspended dust particles, and chemically reactive molecular species. The technology used to generate and sustain plasma will be discussed. Diagnostic probes that can be used to ascertain key aspects of the discharge will be covered. Envisioned application areas for the knowledge include semiconductor processing and electrified chemical processing (e.g., advanced oxidation processes). Students enrolling in this course should have a knowledge of chemical engineering thermodynamics; the physics of electricity and magnetism and electrical circuits; aerosol science and technology; chemical reaction engineering and reactor design; and physical chemistry. Prerequisites: Graduate level standing or permission of instructor
Credit 3 units. EN: TU

E44 EECE 521 Air Quality Engineering with Lab
Introduction to air quality and pollution control. Pollutant emissions, atmospheric chemistry, and fate. Air pollution meteorology and atmospheric dispersion. Application of chemistry, thermodynamics, and fluid mechanics in the selection and design of air pollution control equipment. Labs to measure air quality and demonstrate control principles. Prerequisite: E44 EECE 205 or permission of instructor
Same as E44 EECE 314
Credit 4 units. EN: TU

E44 EECE 531 Environmental Organic Chemistry
This course covers the fundamental physical-chemical examination of organic molecules (focused on anthropogenic pollutants) in aquatic (environmental) systems. Students learn to calculate and predict the chemical properties that are influencing the partitioning of organic chemicals within air, water, sediments and biological systems. This knowledge will be based on understanding intermolecular interactions and thermodynamic principles. Mechanisms of important thermochemical, hydrolytic, redox, and biochemical transformation reactions are also investigated, leading to the development of techniques (e.g., structure-reactivity relationships) for assessing environmental fate or human exposure potential. Prerequisites: E44 EECE 210 or E44 EECE 205; L07 Chem 261; or graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 533 Physical and Chemical Processes for Water Treatment
Water treatment is examined from the perspective of the physical and chemical unit processes used in treatment. The theory and fundamental principles of treatment processes are covered and are followed by the operation of treatment processes. Processes covered include gas transfer, adsorption, precipitation, oxidation-reduction, flocculation, sedimentation, filtration, and membrane processes. Corequisites: E44 EECE 210 or graduate level standing or permission of instructor
Credit 3 units. EN: BME T, TU

E44 EECE 534 Environmental Nanochemistry
This course involves the study of nanochemistry at various environmental interfaces, focusing on colloid, nanoparticle, and surface reactions. The course would also (1) examine the thermodynamics and kinetics of nanoscale reactions at solid-water interfaces in the presence of inorganic or organic compounds and microorganisms; (2) investigate how nanoscale interfacial reactions affect the fate and transport of contaminants; (3) introduce multidisciplinary techniques for obtaining fundamental information about the structure and reactivity of nanoparticles and thin films, and the speciation or chemical form of environmental pollutants at the molecular scale; (4) explore connections between environmental nanochemistry and environmental kinetic analysis at larger scales. This course will help students attain a better understanding of the relationship between nanoscience/technology and the environment-specifically how nanoscience could potentially lead to better water treatments, more

effective contaminated-site remediation, or new energy alternatives. Students enrolling in this course should have a knowledge of general chemistry. Prerequisites: Senior or graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 535 Environmental Data Science
Many of the grand challenges that we face today require understanding and manipulation of processes at the interface of natural and manmade environments. Oftentimes, such knowledge is acquired through data. Skills to effectively visualize and analyze data and build predictive models are valued across different sectors of the society. This is an application-driven course. Prerequisites: L24 Math 217, E35 ESE 318 and (E35 ESE 326 or E60 ENGR 328) or graduate level standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 537 Environmental Resource Recovery
This course will focus on key concepts of resource recovery from wastes. Topics include energy, water, nutrient, and value-added compounds. The course will discuss technological advancements, environmental impacts, and techno-economic assessment of environmental resource recovery. The cutting-edge recovery technologies in full-scale applications or laboratory studies will be introduced. Students will be trained for critical thinking and review of literature information, practice technical analysis and writing, and conduct a concept design of recovery systems using the data from local wastewater treatment facilities. The course is valuable as a prerequisite to more advanced research in environmental engineering, as a technical education to stimulate graduate students' interest in environmental sustainability, and as an introduction to environmental constraints that are increasingly important to other engineering disciplines. Prerequisites: E44 EECE 210 and E44 EECE 409 or graduate level standing or permission of instructor
Credit 3 units.

E44 EECE 551 Metabolic Engineering and Synthetic Biology
Synthetic Biology is a transformative view of biology from "observation approach" to "synthesis approach." It is new "engineering" discipline and aims to make the engineering of new biological function predictable, safe, and quick. It will pave a wide range of applications to transform our views on production of sustainable energy and renewable chemicals, environmental problems, and human disease treatments. The field intersects with Metabolic Engineering in areas such as the design of novel pathways and genetic circuits for product generation and toxic chemical degradation. In this course, the field and its basis are introduced. First, relevant topics in biology, chemistry, physics, and engineering are covered. Second, students will participate in brain-storming and discussion on new biology-based systems. Last, students will design and present new synthetic biology systems to solve real-world problems. No prerequisite. Both undergrad and graduate students can take this course.
Credit 3 units. EN: BME T, TU

E44 EECE 552 Biomass Energy Systems and Engineering
This course offers background in the organic chemistry, biology and thermodynamics related to understanding the conversion of biomass. In addition includes relevant topics relating to biomass feedstock origin, harvest, transportation, storage, processing and pretreatment along with matters concerning thermo- and bio-chemical conversion technologies required to produce fuels, energy, chemicals, and materials. Also, various issues with respect to biomass characterization, economics and environmental impact will be discussed. The main objective of the course is to introduce concepts central to a large-scale integrated biomass bioconversion system. Prerequisites: Senior or graduate level standing or permission of instructor
Credit 3 units. EN: BME T, TU

E44 EECE 554 Molecular Biochemical Engineering
This course is set for junior level graduate students to bridge the gap between biochemical engineering theory and academic research in bioengineering. It will cover common molecular biotechnologies (molecular biology, microbiology, recombinant DNA technology, protein expression etc), biochemical models (enzyme catalysis, microbial growth, bioreactor etc) and bioengineering methodologies (protein engineering, expression control systems etc). These theories and technologies will be introduced in a manner closely related to daily academic research or biochemical industry. Areas of application include biofuel and chemical production, drug discovery and biosynthesis, bioremediation, and environmental applications. This course also contains a lab section (20~30%) that requires students to apply the knowledge learned to design experiments, learn basic experimental skills and solve current research problems. Prerequisites: E44 EECE 101 or E44 EECE 103; L41 Biol 2960 or E44 EECE 306; L41 Biol 4810; or graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 572 Advanced Transport Phenomena
Analytical tools in transport phenomena: Scaling, perturbation and stability analysis. Numerical computations of common transport problem with MATLAB tools. Low Reynolds number flows and applications to microhydrodynamics. Turbulent flow analysis and review of recent advances in numerical modeling of turbulent flows. Convective heat and mass transfer in laminar and turbulent flow systems. Introduction to two phase flow and multiphase reactors. Pressure-driven transport and transport in membranes, electrochemical systems, double layer effects and flow in microfluid devices. Prerequisites: E44 EECE 501 or (E44 EECE 301 and E44 EECE 307), or permission of instructor
Credit 3 units. EN: BME T, TU

E44 EECE 574 Electrochemical Engineering
This course will teach the fundamentals of electrochemistry and the application of the same for analyzing various electrochemical energy sources/devices. The theoretical frameworks of current-potential distributions, electrode kinetics, porous electrode and concentrated solution theory will be presented in the context of modeling, simulation and analysis of electrochemical systems. Applications to batteries, fuel cells, capacitors, copper deposition will be explored. Prerequisites: E44 EECE 501 or E44 EECE 301 and E44 EECE 307; or permission of instructor
Credit 3 units.

E44 EECE 576 Chemical Kinetics and Catalysis
This course reflects the fast, contemporary progress being made in decoding kinetic complexity of chemical reactions, in particular heterogeneous catalytic reactions. New approaches to understanding relationships between observed kinetic behaviour and reaction mechanism will be explained. Present theoretical and methodological knowledge will be illustrated by many examples taken from heterogeneous catalysis (complete and partial oxidation), combustion and enzyme processes. Prerequisite: senior or graduate student standing, or permission of instructor.
Credit 3 units. EN: BME T, TU

E44 EECE 597 EECE Project Management
An introduction to the theory and practice of engineering project management, with an emphasis on projects related to environmental protection and occupational health and safety. Topics include: project definition and justification; project evaluation and selection; financial analysis and cost estimation; project planning, including scheduling,

resourcing, and budgeting; project oversight, auditing, and reporting; and effective project closure. Students will be introduced to commonly used project management tools and systems, such as work breakdown structures, network diagrams, Gantt charts, and project management software. Topics will also include project management in different organizational structures and philosophies; creating effective project teams; and managing projects in international settings. Prerequisites: Enrolled in MEng program; senior or graduate level standing or permission of instructor.
Credit 3 units.

E44 EECE 599 Master's Research
Credit variable, maximum 9 units.

E44 EECE 600 Doctoral Research
Credit variable, maximum 9 units.

PhD in Energy, Environmental & Chemical Engineering (EECE)

The doctoral degree requires a total of 72 credits beyond the bachelor's degree. Of these, a minimum of 36 credits must be graduate course work, and a minimum of 30 credits must be doctoral thesis research units. To be admitted to candidacy, students must have completed at least 18 credits at Washington University, have an overall grade-point average of at least 3.25, and pass the qualifying examination. Note that, to be eligible to take the qualifying exam, students must maintain a 3.25 GPA as described in the EECE PhD handbook. All students are required to enroll in the department seminar every semester to receive passing grades. The first-year students must complete the core curriculum, perform two research rotations, and find a permanent research advisor. Then, within 18 months after the qualifying exam (generally in their third year), students should defend their thesis proposal.

After successful proposal defense, students should provide their research updates through annual meetings or reports with their thesis committee until their graduation. While conducting doctoral research, students should perform in a professional manner in their research lab and/or office setting and be in compliance with all safety and regulatory requirements for their research projects. During the doctoral program, students must satisfy their fundamental and advanced teaching requirements by participating in mentored teaching experiences in the department for two or three semesters, by attending professional development workshops from the Teaching Center, and by presenting at least two formal presentations at the local level or at national or international conferences. Upon completion of their dissertation, students must present their dissertation research in a public forum and successfully defend the dissertation before their thesis committee.

For more detailed guidelines, please refer to the EECE doctoral studies handbook available on the EECE Graduate Degree Programs webpage (https://eece.wustl.edu/graduate/programs/Pages/PhD-Energy-Environmental-Chemical-Eng.aspx).

Master of Science (MS) in Energy, Environmental & Chemical Engineering (EECE)

The MS degree is a research-focused master's program for students interested in studying environmental engineering, energy systems and chemical engineering. This degree is typically a two-year program that requires the completion of course work and may include the completion of a research or thesis project under the supervision of a faculty member.

The program consists of 30 total credits that can be completed in one of three ways:

1. 30 credits of course work;
2. 24 credits of course work and 6 credits of independent study; or
3. 24 credits of course work and 6 credits of thesis research.

The course work for all options is comprised of 15 credits of core courses with remaining elective units (400 or 500 level) chosen with the approval of the advisor. Students must have a cumulative grade-point average of 2.75 or better to receive the degree. The 6 credits of independent study or thesis work are done under the guidance of a tenured or tenure-track faculty member in the department. Research results presented in the form of a written project report must be approved by the advisor and an external reviewer. Research results presented in the form of a thesis must be approved by a three-person faculty committee formed with the approval of the advisor. The completion of the degree program must be consistent with the residency and other applicable requirements of Washington University and the McKelvey School of Engineering.

Doctoral students may also receive an MS in EECE "along the way" in their PhD program. They should have passed the PhD proposal defense, completed 30 units of required course work, and published or submitted at least one peer-reviewed journal manuscript from their thesis research.

For more detailed information, please visit the MS in EECE (https://eece.wustl.edu/graduate/programs/Pages/MS-in-Energy-Environmental-Chemical-Engineering.aspx) webpage.

Master of Engineering (MEng) in Energy, Environmental & Chemical Engineering (EECE)

This professional graduate degree is a master's program based in course work for students interested in state-of-the-art practice in environmental engineering, energy systems and chemical engineering. The master's degree provides students with critical scientific and engineering skill sets; leadership training for management, economics and policy decision; and the opportunity to specialize in specific pathways. The curriculum is geared to enhance skill sets for practice in industry and can be completed by a full-time student in 12 to 18 months.

The program consists of 30 units, with a total of five required core courses in four areas:

- Technical Core (6 units)
- Mathematics (3 units)
- Project Management (3 units)
- Social, Legal, and Policy Aspects (3 units)

Elective courses (400 or 500 level) are selected with the approval of the academic advisor. Up to six elective units may be in the form of an independent study project. All courses comprising the required 30 credits must be taken for a grade (i.e., they cannot be taken pass/fail), and a minimum grade-point average of 2.70 is required for graduation.

Pathways composed of specific elective courses can be completed to result in a certificate of specialization. Available pathways include the following:

- Advanced Energy Technologies
- Bioengineering and Biotechnology
- Environmental Engineering Science
- Energy and Environmental Nanotechnology
- Energy and Environmental Management

For more detailed information, please visit the MEng in EECE webpage (https://eece.wustl.edu/graduate/programs/Pages/MEng-Energy-Environmental-Chemical-Eng.aspx).

Combined Master of Engineering/Master of Business Administration (MEng/MBA)

In recent years, student interest has grown rapidly in the intersection between engineering and business approaches to issues of sustainability, energy, the environment and corporate social responsibility. An interdisciplinary approach is necessary to address these issues with innovative, critical thinking that will lead to practical, effective solutions. This combined program — the Master of Engineering in Energy, Environmental & Chemical Engineering/Master of Business Administration (MEng/MBA), offered by McKelvey School of Engineering and Olin Business School — is well positioned to address this critical intersection.

The Olin MBA curriculum offers a comprehensive set of required and elective courses built upon a foundation of critical-thinking and leadership skills. Olin MBAs are able to shape the curriculum to meet their unique personal objectives and to incorporate the MEng degree requirements.

Both the MEng and the MBA degrees will be awarded simultaneously at the completion of the program.

Please visit the Olin Combined Programs (https://olin.wustl.edu/EN-US/academic-programs/full-time-MBA/academics/joint-degrees/Pages/washu-graduate-programs.aspx) webpage and the EECE MEng/MBA webpage (https://eece.wustl.edu/graduate/programs/Pages/MEngMBA-Program.aspx) for details.

Imaging Science

The PhD in Imaging Science program at Washington University in St. Louis is **one of only two** such programs in the United States. This program offers an interdisciplinary curriculum that focuses on the technology of imaging with applications that range from cancer diagnosis to virtual reality.

What Is Imaging Science?

Imaging science is an interdisciplinary academic discipline that broadly addresses the design and optimization of imaging systems and the extraction of information from images. It builds on contributions from traditional fields such as biomedical engineering, electrical engineering and computer science as well as from physics, applied mathematics, biology and chemistry.

What Can You Do With an Advanced Degree in Imaging Science?

The high demand for personnel with training in imaging science is reflected in government policy and funding opportunities. Many academic, industrial and national laboratory positions exist for highly qualified candidates. Graduates of the program will be prepared for careers in academic research or in industries that require expertise in the quantitative principles of imaging.

Curriculum Focus

- Mathematical and computational principles of image formation
- Image analysis
- Image understanding
- Image quality assessment

This interdisciplinary program is unique in that it brings together expert faculty from the McKelvey School of Engineering (https://engineering.wustl.edu/Pages/home.aspx) and the School of Medicine (https://medicine.wustl.edu/) to provide students with the freedom and flexibility to learn from leading imaging experts and to engage in impactful research.

History

Washington University has been a leader in the technology and advancement of imaging science for more than 125 years. During the 1920s, Washington University researchers were the first to use X-rays to view the gallbladder. During the 1970s, research by Michel Ter-Pogossian at the university's Mallinckrodt Institute of Radiology led to the development of the PET scanner.

Website:	https://engineering.wustl.edu/academics/programs/imaging-science/index.html

Faculty

Jody O'Sullivan (https://engineering.wustl.edu/faculty/Joseph-OSullivan.html)
Co-Director
Samuel C. Sachs Professor of Electrical Engineering
PhD, University of Notre Dame
Electrical & Systems Engineering

Joe Culver (https://www.mir.wustl.edu/employees/joseph-culver/)
Co-Director
Professor
PhD, University of Pennsylvania
Radiology; Biomedical Engineering

Hongyu An (https://www.mir.wustl.edu/employees/hongyu-an/)
Associate Professor
PhD, Washington University
Radiology; Biomedical Engineering

Beau Ances (https://anceslab.wustl.edu/people/beau-ances-md-phd/)
Professor
MD, University of Pennsylvania
PhD, University of Pennsylvania
Neurology; Biomedical Engineering

Deanna Barch (https://psychiatry.wustl.edu/people/deanna-barch-phd/)
Gregory B. Couch Professor of Psychiatry
PhD, University of Illinois
Psychological & Brain Sciences; Biomedical Engineering

Adam Bauer (https://www.mir.wustl.edu/employees/adam-bauer/)
Assistant Professor of Radiology/Assistant Professor of Biomedical Engineering
PhD, Washington University in St. Louis

Phil Bayly (https://engineering.wustl.edu/faculty/Philip-Bayly.html)
Lilyan and E. Lisle Hughes Professor of Mechanical Engineering
PhD, Duke University
Mechanical Engineering & Materials Science

Janine Bijsterbosch (https://www.mir.wustl.edu/employees/janine-bijsterbosch/)
Assistant Professor of Radiology
PhD, University of Sheffield

Aaron Bobick (https://engineering.wustl.edu/faculty/Aaron-Bobick.html)
James M. McKelvey Professor and Dean
PhD, Massachusetts Institute of Technology
Computer Science & Engineering

Hong Chen (https://engineering.wustl.edu/faculty/Hong-Chen.html)
Associate Professor
PhD, University of Washington
Biomedical Engineering

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Assistant Professor of Neuroscience
PhD, Cell and Developmental Biology, Harvard University

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PhD, Washington University in St. Louis

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Radiation Oncology; Biomedical Engineering

Joel Garbow
Professor of Radiology
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Assistant Professor of Radiology
PhD, National Technical University of Athens

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Professor of Developmental Biology
Neuroscience

Roch Guérin (https://engineering.wustl.edu/faculty/Roch-Guerin.html)
Harold B. and Adelaide G. Welge Professor of Computer Science
PhD, California Institute of Technology
Computer Science & Engineering

Dennis Hallahan (https://physicians.wustl.edu/people/dennis-e-hallahan-md-fastro/)
Elizabeth H. and James S. McDonnell III Distinguished Professor of Medicine
MD, Rush University
Radiation Oncology; Biomedical Engineering

Edward Han
Assistant Professor of Neuroscience
PhD, University of California, San Diego

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Alan A. and Edith L. Wolff Professor of Neuroscience
PhD, Princeton University
Neuroscience; Biomedical Engineering

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Associate Professor
PhD, Washington University in St. Louis
Biomedical Engineering

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Radiation Oncology; Biomedical Engineering

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PhD, University of Arizona
Biomedical Engineering; Radiology

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PhD, Rice University
Computer Science & Engineering

Ulugbek Kamilov (https://engineering.wustl.edu/faculty/Ulugbek-Kamilov.html)
Assistant Professor
PhD, École Polytechnique Fédérale de Lausanne, Switzerland
Computer Science & Engineering; Electrical & Systems Engineering

Gregory Lanza (https://cardiology.wustl.edu/faculty/gregory-m-lanza-md-phd-facc/)
Oliver M. Langenberg Chair, Distinguished Professor of the Science and Practice of Medicine
MD, Northwestern University
PhD, University of Georgia
Medicine; Biomedical Engineering

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Professor
PhD, University of Laval, Canada
Radiology

Matthew Lew (https://engineering.wustl.edu/faculty/Matthew-Lew.html)
Assistant Professor
PhD, Stanford University
Electrical & Systems Engineering

Jin-Moo Lee
Andrew B. and Gretchen P. Jones Professor of Neurology
MD/PhD, Weill Cornell Medical College
Biomedical Engineering; Neurology; Radiology

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Professor
PhD, Washington University
Radiology; Biomedical Engineering

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Instructor in Radiology
PhD, Biomedical Engineering, Vanderbilt University

Philip Payne (https://publichealth.wustl.edu/scholars/philip-r-payne/)
Robert J. Terry Professor
PhD, Columbia University
Medicine; Biomedical Engineering

David Piston (https://pistonlab.wustl.edu/)
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PhD, University of Illinois
Cell Biology & Physiology; Biomedical Engineering

Barani Raman
Professor
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PhD, University of Tennessee
Department of Radiology

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Professor
PhD, University of California, Los Angeles
Radiology; Biomedical Engineering

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Assistant Professor
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Radiology

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Assistant Professor of Radiology
PhD, Ecole Centrale Paris

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Pathology & Immunology; Biomedical Engineering

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Associate Professor
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Radiology; Biomedical Engineering

Daniel Thorek
Associate Professor
PhD, University of Pennsylvania
Radiology; Biomedical Engineering

David Van Essen (https://profiles.wustl.edu/en/persons/david-van-essen/)
Alumni Endowed Professor
PhD, Harvard University
Neuroscience; Biomedical Engineering

Richard Wahl (https://wuphysicians.wustl.edu/for-patients/find-a-physician/richard-leo-wahl/)
Elizabeth E. Mallinckrodt Professor of Radiology
MD, Washington University
Radiology

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Associate Professor
PhD, Washington University
Obstetrics & Gynecology; Radiology; Biomedical Engineering

Muriah Wheelock
Assistant Professor of Radiology
PhD, University of Alabama at Birmingham

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HM Wilson Professor of Radiology
MD, Duke University
Radiology; Biomedical Engineering

Lan Yang
Edwin H. & Florence G. Skinner Professor
PhD, California Institute of Technology
Electrical & Systems Engineering

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Associate Professor
PhD, University of Wisconsin-Madison
Radiation Oncology; Biomedical Engineering

Jie Zheng (https://www.mir.wustl.edu/employees/jie-zheng/)
Associate Professor
PhD, University of Cincinnati
Radiology; Biomedical Engineering

Chao Zhou (https://engineering.wustl.edu/faculty/Chao-Zhou.html)
Associate Professor
PhD, Physics, University of Pennsylvania
Biomedical Engineering

Quing Zhu (https://engineering.wustl.edu/faculty/Quing-Zhu.html)
Professor
PhD, University of Pennsylvania
Biomedical Engineering

Professor Emeritus

Martin Arthur (https://engineering.wustl.edu/faculty/Martin-Arthur.html)
Newton R. and Sarah Louisa Glasgow Wilson Professor of Engineering
PhD, University of Pennsylvania
Electrical & Systems Engineering

Degree Requirements

- PhD in Imaging Science (p. 77)
- Master of Science (MS) in Imaging Science (p. 80)

Courses

For information regarding courses, please refer to the Degree Requirements (p. 77) section of this page.

PhD in Imaging Science (Interdisciplinary PhD)

Requirements

To complete the PhD in Imaging Science, students must do the following:

- Maintain an average grade of B (3.0 grade-point average) for all 72 units (up to 24 graduate units may be transferred with approval)
- Complete courses with no more than one grade below B-
- Complete at least one semester-long research rotation
- Become integrated with a research group
- Pass a qualifying exam
- Successfully defend a thesis proposal
- Present and successfully defend a dissertation
- Complete one mentored teaching experience, including workshops and other related requirements

Courses

Required Core Courses (19 units)

Code	Title	Units
BME 570	Mathematics of Imaging Science (or equivalent CSE or ESE course)	3
ESE 596	Seminar in Imaging Science and Engineering	1
ESE 520	Probability and Stochastic Processes	3

BME 601C	Research Rotation for BME Doctoral Students (refer to the Research Rotations section later on this page)	3
ESE 5932	Computational Methods for Imaging Science	3
ESE 5933	Theoretical Imaging Science	3
ESE 5934	Practicum in Imaging Science	3
Total Units		**19**

Elective Imaging Courses from any of the Following Categories (at least 12 units):

- Computational Imaging & Theory
- Imaging Sensors & Instrumentation
- Image Formation & Imaging Physics
- Translational Biomedical Imaging
- Medical Physics

Typical Progression of Courses

Course	Fall Units	Spring Units
First Year		
Mathematics of Imaging Science (BME 570) (or equivalent CSE or ESE course)	3	—
Seminar in Imaging Science and Engineering (ESE 596)	1	—
Research Rotation for BME Doctoral Students (BME 601C) (refer to the Research Rotations section later on this page)	3	—
Elective	3	—
Biological Imaging Technology (ESE 589)	—	3
Computational Methods for Imaging Science (ESE 5932)	—	3
Elective or optional second research rotation (BME 601)	—	3
	10	**9**
Second Year		
Theoretical Imaging Science (ESE 5933)	3	—
Elective or doctoral research	6	6
Practicum in Computational Imaging (BME XXX) (or equivalent CSE or ESE course)	—	3
	9	**9**

Elective Options

Elective Courses — Computational Imaging & Theory

Code	Title	Units
CSE 412A	Introduction to Artificial Intelligence	3
CSE 501N	Introduction to Computer Science	3
CSE 513T	Theory of Artificial Intelligence and Machine Learning	3
CSE 515T	Bayesian Methods in Machine Learning	3
CSE 517A	Machine Learning	3
CSE 519T	Advanced Machine Learning	3
CSE 543T	Algorithms for Nonlinear Optimization	3
CSE 546T	Computational Geometry	3
CSE 554A	Geometric Computing for Biomedicine	3
CSE 559A	Computer Vision	3
CSE 566S	High Performance Computer Systems	3
ESE 523	Information Theory	3
ESE 524	Detection and Estimation Theory	3
ESE 588	Quantitative Image Processing	3

Elective Courses — Image Formation & Imaging Physics

Code	Title	Units
BME 494	Ultrasound Imaging	3
BME 5820	Fundamentals and Applications of Modern Optical Imaging	3
or ESE 582	Fundamentals and Applications of Modern Optical Imaging	
BME 591	Biomedical Optics I: Principles	3
BME 594	Ultrasound Imaging	3
BME 5XX	Imaging in Nuclear Medicine (to be developed)	
BME 5XX	Magnetic Resonance Imaging (to be developed)	

Elective Courses — Medical Physics

Code	Title	Units
BME 507	Radiological Physics and Dosimetry	3
BME 5071	Radiobiology	2
BME 5072	Radiation Therapy Physics	3
BME 5073	Radiation Protection and Safety	2

Approved Life Science Courses

Code	Title	Units
BME 530A	Molecular Cell Biology for Engineers	3
BME 538	Cell Signal Transduction	3
BME 5902	Cellular Neurophysiology	3
Biol 404	Laboratory of Neurophysiology	4
Biol 4071	Developmental Biology	3
Biol 4580	Principles of Human Anatomy and Development	3
Biol 4810	General Biochemistry I	3
Biol 4820	General Biochemistry II	3
Biol 5053	Immunobiology I	4
Biol 5068	Fundamentals of Molecular Cell Biology	4
Biol 5146	Principles and Applications of Biological Imaging	3
Biol 5147	Contrast Agents for Biological Imaging	3
or Chem 5147	Contrast Agents for Biological Imaging	
Biol 5224	Molecular, Cell and Organ Systems	3
Biol 5285	Current Topics in Human and Mammalian Genetics	3
Biol 5319	Molecular Foundations of Medicine	3
Biol 5352	Developmental Biology	3
Biol 548	Nucleic Acids & Protein Biosynthesis	3
Biol 5488	Genomics	variable; max. 4
Biol 5571	Cellular Neurobiology	6
Biol 5651	Neural Systems	4
Biol 5663	Neurobiology of Disease	2

Approved Mathematics Courses

Any graduate-level course within the Department of Mathematics and Statistics is approved.

Research Rotations

During their first year, students are required to register for and complete at least one research rotation (3 units) with program faculty mentors. The research rotations allow students to sample different research projects and laboratory working environments before selecting the group in which they will carry out their PhD dissertation research.

A rotation will be chosen in consultation with program faculty and must be mutually agreeable to both the student and the mentor. At the completion of each rotation, the student must submit to the mentor and director a written report approved by the mentor.

Qualifying Exam

The qualifying exam will be administered during the spring of the student's second year of graduate school. The examining committee, which will develop and grade the exam, will consist of three members of the Imaging Science PhD Program Committee. The director of the graduate program will approve the committee, the members of which will be suggested by the thesis advisor.

Students will choose three out of the following four exam topics:

- Mathematics of Imaging Science
- Imaging Physics & Image Formation Methods
- Image Analysis & Data-Driven Imaging
- Theoretical Image Science

Finding a Thesis Research Mentor

Because the PhD is a research degree, the student is expected to become integrated within a research group. By the end of the first year of study, students should have found a thesis advisor who will oversee their PhD research and assume financial responsibility for their stipend, tuition, health insurance and student fees. The thesis advisor must be a faculty member on the Imaging Science PhD Program Committee with the title of professor, associate professor or assistant professor. Failure to find a research advisor by May 1 will result in the student being placed on probation that can last until August 31. During that time, the student must continue to seek a research advisor. Failure to find a research advisor by August 31 will lead to dismissal from the PhD program and termination of funding.

Research Presentation/Thesis Proposal

Before the end of their third year, the student will give an oral presentation of their proposed PhD project — with the necessary background to support it — to the Research Advisory Committee. This committee must follow all guidelines for PhD degrees in the McKelvey School of Engineering and consists of five members (the dissertation research mentor plus four other members) with the following requirements:

- No more than three faculty members with primary appointment from any one department;
- Four of the members must be tenured or tenure-track faculty at Washington University;
- Three of the members must be imaging science program faculty members;
- If requested by the research mentor and approved by the co-directors, a sixth member may be added to the committee.

The committee will be chaired by the PhD mentor. At least two weeks prior to the presentation, the student will present a written document outlining the research background, proposed procedures, preliminary results and plans for completion. The required document will typically be between 15 and 30 pages in length, and it must contain a comprehensive bibliography.

The student will be placed on probation if they fail to pass their thesis proposal by the sixth semester. The student will be given a second opportunity to pass the exam during their seventh semester. If the student passes the second exam and meets the other program requirements (e.g., grades), they may continue the program without prejudice. If the student fails the exam a second time, they will be terminated from the PhD program.

Dissertation

The student will prepare a written dissertation for examination by the Research Advisory Committee, now referred to as the Dissertation Defense Committee. The student will defend the dissertation before this committee. Should a member of this committee be unable to participate, the director of the graduate program, in consultation with the Associate Dean, will choose a replacement. If the committee members feel that the dissertation has deficiencies, they may recommend that the candidate address them and send the revised dissertation to the committee members for approval. The committee may also recommend that the candidate present another oral defense of the modified work. The Committee will inform the director of the graduate program, and they will warn the student in writing that the student must submit a revised dissertation and pass the oral defense (if recommended) in order to complete the PhD program. If, after revision and reexamination, the Committee still finds deficiencies and cannot reach unanimous agreement to approve the dissertation, the policy from the Office of the Provost on Dissenting Votes will apply.

Teaching Requirements

Students in the PhD program will receive formal pedagogical training by attending a minimum of two teaching workshops offered by the Center for Teaching and Learning (https://teachingcenter.wustl.edu/events/). They will be expected to fulfill the teaching requirements of their designated administrative home departments. The teaching requirements must be completed before the students submit their doctoral dissertations to the McKelvey Registrar.

Master of Science (MS) in Imaging Science

Requirements

The Master of Science (MS) in Imaging Science requires the completion of 30 credit units, including 13 credit units from the core list (two mathematics and physics courses, one seminar course, and one computation and one application course each selected from the list below) and the remaining credits from the electives list.

Courses

Required Core Imaging Science Courses (13 units)

Mathematics and Physics of Imaging Modalities Courses (6 units)

Code	Title	Units
BME 570	Mathematics of Imaging Science (or CSE/ESE 5931)	3
BME 5820	Fundamentals and Applications of Modern Optical Imaging	3
or ESE 582	Fundamentals and Applications of Modern Optical Imaging	
BME 589	Biological Imaging Technology	3
or ESE 589	Biological Imaging Technology	
BME 591	Biomedical Optics I: Principles	3
BME 594	Ultrasound Imaging	3

Computational Imaging Courses (3 units)

Code	Title	Units
CSE 417T	Introduction to Machine Learning	3
CSE 515T	Bayesian Methods in Machine Learning	3
CSE 517A	Machine Learning	3
ESE 415	Optimization	3
ESE 417	Introduction to Machine Learning and Pattern Classification	3
ESE 5932	Computational Methods for Imaging Science	3

Imaging Applications Courses (3 units)

Code	Title	Units
BME 544	Biomedical Instrumentation	3
BME 592	Biomedical Optics II: Imaging	3
CSE 559A	Computer Vision	3

Seminar Course (1 unit)

Code	Title	Units
ESE 596	Seminar in Imaging Science and Engineering (or BME 596)	1

Additional Electives (30 units)

Students may choose from the list below and the lists above to meet the 30 units required:

Code	Title	Units
Biol 5146	Principles and Applications of Biological Imaging	3
Biol 5147	Contrast Agents for Biological Imaging	3
BME 500	Independent Study	3
BME 599	Master Research	6
CLNV 510	Ethical and Legal Issues in Clinical Research	2
ESE 438	Applied Optics (or ESE 538A)	3
ESE 520	Probability and Stochastic Processes	3
ESE 5933	Theoretical Imaging Science (or BME 5933)	3
ESE 5934	Practicum in Imaging Science	3

Materials Science & Engineering

The Institute of Materials Science & Engineering (IMSE) at Washington University in St. Louis offers a unique, interdisciplinary PhD in Materials Science & Engineering that crosses traditional departmental and school boundaries. The field of materials science and engineering focuses on the study, development and application of new materials with desirable properties, with the goal of enabling new products and superior performance regimes. Disciplines in the physical sciences (e.g., chemistry, physics) play a central role in developing the fundamental knowledge that is needed to design materials for a variety of engineering applications (e.g., mechanical engineering, electrical engineering, biomedical engineering). Building on training that spans from fundamental to applied sciences, materials scientists and engineers integrate this fundamental knowledge to develop new materials and match them with appropriate technological needs.

The IMSE is well positioned to address the needs of a student seeking a truly interdisciplinary experience. The IMSE brings together a diverse group of faculty from departments in Arts & Sciences, the McKelvey School of Engineering, and the School of Medicine. The IMSE also oversees shared research and instrument facilities, develops partnerships with industry and national laboratories, and facilitates outreach activities.

Current focused areas of research and advanced graduate education within the IMSE include the following:

- Artificial intelligence in materials discovery and design
- Biomedical, bio-derived, and bio-inspired materials
- Materials for energy and environmental technologies
- Quantum and photonic materials and devices

Contact:	Beth Gartin
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Faculty

Director

Katharine M. Flores (https://engineering.wustl.edu/faculty/Katharine-Flores.html)
Christopher I. Byrnes Professor, Mechanical Engineering & Materials Science
PhD, Stanford University

Professor Flores' primary research interest is the mechanical behavior of high-performance structural materials, with particular emphasis on understanding structure-processing-property relationships in bulk metallic glasses and their composites.

Professors

Jianjun Guan (https://engineering.wustl.edu/faculty/Jianjun-Guan.html)
Professor, Mechanical Engineering & Materials Science
PhD, Zhejiang University

Professor Guan's research interests are in biomimetic biomaterials synthesis and scaffold fabrication; bioinspired modification of biomaterials; injectable and highly flexible hydrogels; bioimageable polymers for MRI and EPR imaging and oxygen sensing; mathematical modeling of scaffold structural and mechanical properties; stem cell differentiation; neural stem cell transplantation for brain tissue regeneration; and bone and cardiovascular tissue engineering.

Kenneth F. Kelton (https://physics.wustl.edu/people/kenneth-f-kelton/)
Arthur Holly Compton Professor of Arts & Sciences, Physics
PhD, Harvard University

Professor Kelton is involved in the study and production of titanium-based quasicrystals and related phases; fundamental investigations of time-dependent nucleation processes; modeling of oxygen precipitation in single crystal silicon; structure of amorphous materials; relation between structure and nucleation barrier; and hydrogen storage in quasicrystals.

Vijay Ramani (https://engineering.wustl.edu/Profiles/Pages/Vijay-Ramani.aspx)
Roma B. & Raymond H. Wittcoff Distinguished University Professor of Environment & Energy
PhD, University of Connecticut

Vijay Ramani's research interests lie at the confluence of electrochemical engineering, materials science and renewable and sustainable energy technologies. The National Science Foundation, Office of Naval Research, ARPA-E, and Department of Energy have funded his research, with mechanisms including an NSF CAREER award (2009) and an ONR Young Investigator Award (ONR-YIP; 2010).

Srikanth Singamaneni (https://engineering.wustl.edu/Profiles/Pages/Srikanth-Singamaneni.aspx)
The Lilyan & E. Lisle Hughes Professor, Mechanical Engineering & Materials Science
PhD, Georgia Institute of Technology

Professor Singamaneni's research interests include plasmonic engineering in nanomedicine (in vitro biosensing for point-of-care diagnostics, molecular bioimaging, nanotherapeutics); photovoltaics (plasmonically enhanced photovoltaic devices); surface-enhanced Raman scattering (SERS)-based chemical sensors, with particular emphasis on the design and fabrication of unconventional and highly efficient SERS substrates; hierarchical organic/inorganic nanohybrids as multifunctional materials; bioinspired structural and functional materials; polymer surfaces and interfaces; responsive and adaptive materials and scanning probe microscopy; and surface force spectroscopy of soft and biological materials.

Fuzhong Zhang (https://engineering.wustl.edu/faculty/Fuzhong-Zhang.html)
Professor, Energy, Environmental & Chemical Engineering
PhD, University of Toronto

Professor Zhang's research focuses on developing synthetic biology tools and systems for the sustainable production of structurally defined chemicals and high-performance materials. Current research projects include the following: (1) engineering microbial metabolic dynamics and heterogeneity; (2) engineering metabolic pathways to produce structure-defined biofuels and chemicals; and (3) developing microbial factories to produce high-performance materials.

Associate Professors

Mikhail Y. Berezin (https://profiles.wustl.edu/en/persons/mikhail-berezin/)
Associate Professor, Radiology
PhD, Moscow Institute of Oil and Gas/Institute of Organic Chemistry

Dr. Berezin's lab focuses on the development of novel optically active probes ranging from small molecules to nanoparticles and the development of optical instrumentation for spectroscopy and imaging using knowledge of excited states. The lab's research interest lies in the investigation and application of molecular excited states and their reactions for medical imaging and clinical treatment.

Marcus Foston (https://engineering.wustl.edu/faculty/Marcus-Foston.html)
Associate Professor, Energy, Environmental & Chemical Engineering
PhD, Georgia Institute of Technology

Professor Foston's research program seeks to develop innovative and novel routes to exploit and utilize lignocellulosic biomass by taking advantage of materials involved in industries such as agriculture, papermaking, and forestry products.

Matthew Lew (https://engineering.wustl.edu/faculty/Matthew-Lew.html)
Associate Professor, Electrical & Systems Engineering
PhD, Stanford University

Professor Lew and his students build advanced imaging systems to study biological and chemical systems at the nanoscale, leveraging innovations in applied optics, signal and image processing, design optimization, and physical chemistry. Their advanced nanoscopes (microscopes with nanometer resolution) visualize the activity of individual molecular machines inside and outside living cells. Examples of new technologies developed in the Lew Lab include (1) using tiny fluorescent molecules as sensors that can detect amyloid proteins; (2) designing new "lenses" to create imaging systems that can visualize how molecules move and tumble; and (3) new imaging software that minimizes artifacts in super-resolution images.

Rohan Mishra (https://engineering.wustl.edu/faculty/Rohan-Mishra.html)
Associate Professor, Mechanical Engineering & Materials Science
PhD, Ohio State University

Professor Mishra's research interest is to develop quantitative structure-property correlations in materials starting from the atomic scale. To develop such correlations, his group synergistically combines electronic structure calculations with atomic-resolution electron microscope imaging and spectroscopy. The end goal is the rational design of materials with properties tailored for electronic, optical, magnetic and energy applications. Current research topics include perovskite materials for photovoltaic and optoelectronic applications, novel electrocatalysts, oxidizers, and wide-bandgap semiconductors.

Jai Rudra (https://engineering.wustl.edu/faculty/Jai-Rudra.html)

Associate Professor, Biomedical Engineering
PhD, Louisiana Tech University

Jai Rudra's lab is interested in the development of nanoscale biomaterials such as nanofibers, nanoparticles, virus-like particles, and hydrogels for engaging the immune system to induce protective antibody and cell-mediated immune responses against diseases such as tuberculosis, melanoma, and flavivirus infections (i.e., West Nile and Zika). He is also investigating the development of vaccines against drugs of addiction such as cocaine.

Elijah Thimsen (https://engineering.wustl.edu/faculty/Elijah-Thimsen.html)
Associate Professor, Energy, Environmental & Chemical Engineering
PhD, Washington University in St. Louis

Professor Thimsen's research focus is on the synthesis of nanostructured materials and molecular chemicals using non-equilibrium plasma and aerosol approaches.

Assistant Professors

Sang-Hoon Bae (https://engineering.wustl.edu/faculty/Sang-Hoon-Bae.html)
Assistant Professor, Mechanical Engineering & Materials Science
PhD, University of California, Los Angeles

Professor Bae's research group focuses on tackling the challenges in materials science with thermodynamics, kinetics, and solid-state physics.

Peng Bai (https://engineering.wustl.edu/faculty/Peng-Bai.html)
Assistant Professor, Energy, Environmental & Chemical Engineering
PhD, Tsinghua University, Beijing

Professor Bai's research focuses on the development of next-generation batteries. Knowledge and tools developed in the Bai Group also apply to and benefit the design of other electrochemical energy systems, like supercapacitors and fuel cells.

Erik Henriksen (https://physics.wustl.edu/people/erik-henriksen/)
Assistant Professor, Physics
PhD, Columbia University

Professor Henriksen's lab research is centered on the properties of electrons confined to two dimensions. This remarkable system has yielded a tremendous amount of interesting and important physics over the past several decades, from the integer and fractional quantum Hall effects to the groundbreaking discoveries of graphene and other atomically thin crystals and especially to the recent realization of the topological nature of the electronic structure of a surprising number of materials both novel and familiar.

Nathaniel Huebsch (https://engineering.wustl.edu/faculty/Nathaniel-Huebsch.html)
Assistant Professor, Biomedical Engineering
PhD, Harvard University

Professor Huebsch's research focus is in basic and translational stem cell mechanobiology, with specific focus on hydrogels to control cell-mediated tissue repair and three-dimensional, iPSC-based heart-in-a-dish models to study the influence of mechanical loading and genetics on arrhythmia and contractility.

Sheng Ran (https://physics.wustl.edu/people/sheng-ran/)
Assistant Professor, Physics
PhD, Iowa State University

Professor Ran's research aims to realize and understand exotic states of quantum materials using combined techniques of bulk crystal synthesis, electric and thermal transport measurements under extreme temperature, pressure and magnetic field conditions, and neutron and high-energy X-ray scattering.

Chuan Wang (https://engineering.wustl.edu/faculty/Chuan-Wang.html)
Assistant Professor, Electrical & Systems Engineering
PhD, University of Southern California

Professor Wang's research focus is on two-dimensional semiconductor nanoelectronics and optoelectronics, stretchable electronics, printed electronics, and sensors and actuators.

Patricia Weisensee (https://engineering.wustl.edu/faculty/Patricia-Weisensee.html)
Assistant Professor, Mechanical Engineering & Materials Science
PhD, University of Illinois at Urbana-Champaign

Professor Weisensee's work focuses on understanding the interplay of fluid dynamics, heat transfer, and liquid-solid interactions of droplets and other multi-phase systems. Practical applications of interest are phase change heat transfer for thermal management, thermal storage, water harvesting, metallic additive manufacturing, and droplet interactions with biological and natural systems.

Chong Zhu (https://physics.wustl.edu/people/chong-zu/)
Assistant Professor, Physics
PhD, Tsinghua University

Professor Zu's research interests lie at the interface between atomic, molecular, and optical physics; condensed matter physics; and quantum information.

Degree Requirements

Interdisciplinary PhD in Materials Science & Engineering

To earn a PhD degree, students must complete the requirements of the McKelvey School of Engineering, along with program-specific requirements. Courses include the following:

- Four IMSE Core Courses (12 units)

Code	Title	Units
MEMS 5610	Quantitative Materials Science & Engineering	3
Physics 537	Kinetics of Materials	3
EECE 502	Advanced Thermodynamics in EECE (or a new thermodynamics course to be offered through MEMS in Fall 2023)	3
Chem 5620	Solid-State and Materials Chemistry (or Physics 5072 Solid State Physics)	3
Total Units		**12**

- Two semesters of IMSE 500 First-Year Research Rotation (6 units)
- Three courses (9 units) from a preapproved list of Materials Science & Engineering electives
- A minimum of three graduate-level technical elective courses (9 units) in mathematics or any science or engineering department, to reach a total of at least 36 academic credit units
    - A maximum of 3 units of IMSE 505 Material Science Journal Club will be permitted toward this requirement.
    - Any 400-level courses not included on the preapproved list of Materials Science & Engineering electives must be approved by the Graduate Studies Committee.
- A maximum of 12 units of 400-level courses may be applied toward the required 36 academic credit units. Undergraduate-only courses (below the 400 level) are generally not permitted and may not be used to fulfill this requirement.
- IMSE 501 IMSE Graduate Seminar every semester of full-time enrollment

- 18 to 36 units of IMSE 600 Doctoral Research (Students must identify an IMSE faculty member willing and able to support their dissertation research on a materials-related topic.)
- Students must maintain a grade-point average of at least 3.0 for all graded courses and have no more than one grade of B- or below in a core course or a Materials Science & Engineering elective.

Additional program requirements include the following:

- Pass the IMSE Qualifying Examination (oral and written components)
- Identify an IMSE graduate program faculty member willing and able to support the student's dissertation research on a materials-related topic
- Maintain satisfactory research progress on a topic in materials science and engineering, as determined by the dissertation advisor and the mentoring committee
- Successfully complete research ethics training by the end of the third semester
- Successfully complete teaching requirements by the end of the third year:
  - Attend two or more Teaching Center workshops
  - Complete 15 units of Mentored Teaching Experience
- Successfully complete the dissertation proposal and presentation, with approval from the dissertation examination committee
- Successfully complete and defend a PhD dissertation, with final approval from the dissertation examination committee

Failure to meet these requirements will result in dismissal from the program.

Recommended Course Plan

Year 1

Fall Semester (12 credits)

- IMSE First-Year Research Rotation IMSE 500
- IMSE Graduate Seminar (IMSE 501)
- Quantitative Materials Science & Engineering (MEMS 5610)
- Graduate course on advanced thermodynamics of materials (EECE 502 or new MEMS course in development)*
- Elective

* Students entering in Fall 2022 will complete their thermodynamics requirements in Fall 2023. These students should take an additional elective in Fall 2022.

Spring Semester (12 credits)

- IMSE First-Year Research Rotation IMSE 500
- IMSE Graduate Seminar (IMSE 501)
- Kinetics of Materials (Physics 537)
- Solid State Physics (Physics 5072) (if Chem 5620 not taken in Fall) or elective
- Elective

Summer

- Begin dissertation research
- Prepare for IMSE Qualifying Examination (typically taken in August):
  - Written document and oral presentation on research rotation
  - Oral examination on fundamentals from core courses
- Participate in Graduate Student Mentored Teaching Orientation offered through the Teaching Center in August

Years 2 and Beyond

- *Fall 2022-entry students only:* Complete EECE 502 Advanced Thermodynamics in EECE or new course on thermodynamics of materials to be offered by MEMS in Fall 2023
- Complete remaining electives (discuss with dissertation advisor)
- IMSE Graduate Seminar (IMSE 501)
- Doctoral Research (IMSE 600)
- Teaching requirements (to be completed by the end of the third year):
  - Attend two or more Teaching Center workshops
  - Complete 15 units of Mentored Teaching Experience
- Regular meetings (at least once per year) with the mentoring committee
- Dissertation proposal and presentation (fifth semester)
- Dissertation and oral defense

Mechanical Engineering & Materials Science

The Department of Mechanical Engineering & Materials Science offers both **PhD** and **DSc** programs in **Mechanical Engineering** and **Aerospace Engineering** as well as a **DSc in Materials Science**. The department's research strengths include biomechanics and biotechnology, energy and sustainability, advanced materials and aerospace systems. The doctoral student works in conjunction with their advisor to design the program of study and the research project. The dissertation is defended at the end of the research effort. A typical time to PhD after the completion of the undergraduate engineering degree is four to five years, but the length of the program may vary, depending on the individual and the area of study.

The Department of Mechanical Engineering & Materials Science offers a **Master of Science (MS)** degree in **Mechanical Engineering, Aerospace Engineering,** or **Materials Science and Engineering**. The department also offers a **Master of Engineering in Mechanical Engineering** for those coming from fields closely related to mechanical engineering. The MS degrees can be completed using either a course option or a thesis option. For the thesis option, the student will work closely with a faculty advisor on the thesis project. A typical time for the completion of an MS or MEng degree is one and one-half to two years, with the thesis option usually taking longer than the course option.

Faculty contact for the PhD program: Amit Pathak (https://engineering.wustl.edu/faculty/Amit-Pathak.html)

Faculty contact for the MS and DSc programs: David Peters (https://engineering.wustl.edu/faculty/David-Peters.html)

Faculty contact for the MS in Materials Science & Engineering: Katharine Flores (https://engineering.wustl.edu/faculty/Katharine-Flores.html)

Website:	https://mems.wustl.edu/academics/graduate/index.html

Faculty

Chair

Philip V. Bayly (https://engineering.wustl.edu/faculty/Philip-Bayly.html)
The Lee Hunter Distinguished Professor of Mechanical Engineering
PhD, Duke University
Nonlinear dynamics, vibrations, biomechanics

Associate Chairs

David A. Peters (Mechanical Engineering) (https://engineering.wustl.edu/faculty/David-Peters.html)
McDonnell Douglas Professor of Engineering
PhD, Stanford University
Aeroelasticity, vibrations, helicopter dynamics, aerodynamics

Katharine M. Flores (Materials Science) (https://engineering.wustl.edu/faculty/Katharine-Flores.html)
Christopher I. Byrnes Professor of Engineering
PhD, Stanford University
Mechanical behavior of structural materials

Endowed Professors

Ramesh K. Agarwal (https://engineering.wustl.edu/faculty/Ramesh-Agarwal.html)
William Palm Professor of Engineering
PhD, Stanford University
Computational fluid dynamics, computational physics

Guy M. Genin (https://engineering.wustl.edu/faculty/Guy-Genin.html)
Harold & Kathleen Faught Professor of Mechanical Engineering
PhD, Harvard University
Solid mechanics, fracture mechanics

Mark J. Jakiela (https://engineering.wustl.edu/faculty/Mark-Jakiela.html)
Lee Hunter Professor of Mechanical Design
PhD, University of Michigan
Mechanical design, design for manufacturing, optimization, evolutionary computation

Srikanth Singamaneni (https://engineering.wustl.edu/faculty/Srikanth-Singamaneni.html)
Lilyan and E. Lisle Hughes Professor of Mechanical Engineering
PhD, Georgia Institute of Technology
Microstructures of cross-linked polymers

Professors

Jianjun Guan (https://engineering.wustl.edu/faculty/Jianjun-Guan.html)
PhD, Zhejiang University
Biomimetic biomaterials synthesis, scaffold fabrication

Jessica E. Wagenseil (https://engineering.wustl.edu/faculty/Jessica-Wagenseil.html)
DSc, Washington University
Arterial biomechanics

Associate Professors

Spencer P. Lake (https://engineering.wustl.edu/faculty/Spencer-Lake.html)
PhD, University of Pennsylvania
Soft-tissue biomechanics

Xianglin Li
PhD, University of Connecticut
Multiphase heat and mass transfer in energy systems; computational fluid dynamics

J. Mark Meacham (https://engineering.wustl.edu/faculty/Mark-Meacham.html)
PhD, Georgia Institute of Technology
Micro-/nanotechnologies for thermal systems and the life sciences

Rohan Mishra (https://engineering.wustl.edu/faculty/Rohan-Mishra.html)
PhD, The Ohio State University
Computational materials science

Amit Pathak (https://engineering.wustl.edu/faculty/Amit-Pathak.html)
PhD, University of California, Santa Barbara
Cellular biomechanics

Assistant Professors

Matthew R. Bersi (https://engineering.wustl.edu/faculty/Matthew-Bersi.html)
PhD, Yale University
Biomedical engineering

Sang-Hoon Bae
PhD, University of California, Los Angeles
Materials growth, optoelectronics, renewable energy

Patricia B. Weisensee (https://engineering.wustl.edu/faculty/Patricia-Weisensee.html)
PhD, University of Illinois at Urbana-Champaign
Thermal fluids

Professors of the Practice

Kashif Masud Awan (https://engineering.wustl.edu/faculty/Kashif-Masud-Awan.html)
PhD, University of Ottawa
Biosensors, quantum computers, optical communication

Swami Karunamoorthy (https://engineering.wustl.edu/faculty/Swami-Karunamoorthy.html)
DSc, Washington University
Helicopter dynamics, engineering education

Teaching Professors

Emily J. Boyd (https://engineering.wustl.edu/faculty/Emily-Boyd.html)
PhD, University of Texas at Austin
Thermofluids

Ruth J. Okamoto (https://engineering.wustl.edu/faculty/Ruth-Okamoto.html)
DSc, Washington University
Biomechanics, solid mechanics

Research Assistant Professor

Hong Niu (https://engineering.wustl.edu/faculty/Hong-Niu.html)
PhD, Ohio State University
Biomaterials, regenerative medicine

Joint Faculty

Richard L. Axelbaum (Energy, Environmental & Chemical Engineering) (https://engineering.wustl.edu/faculty/Richard-Axelbaum.html)
Stifel & Quinette Jens Professor of Environmental Engineering Science
PhD, University of California, Davis
Combustion, nanomaterials

Elliot L. Elson (Biochemistry & Molecular Biophysics) (https://profiles.wustl.edu/en/persons/elliot-elson/)
Professor Emeritus of Biochemistry & Molecular Biophysics
PhD, Stanford University
Biochemistry, molecular biophysics

Michael D. Harris (Physical Therapy, Orthopaedic Surgery, and Mechanical Engineering & Materials Science) (https://pt.wustl.edu/people/michael-d-harris-phd/)
PhD, University of Utah
Whole body and joint-level orthopaedic biomechanics

Kenneth F. Kelton (Physics) (https://physics.wustl.edu/people/kenneth-f-kelton/)
Arthur Holly Compton Professor of Arts & Sciences
PhD, Harvard University
Study and production of titanium-based quasicrystals and related phases

Eric C. Leuthardt (Neurological Surgery and Biomedical Engineering) (https://neurosurgery.wustl.edu/people/eric-c-leuthardt-md/)
MD, University of Pennsylvania School of Medicine
Neurological surgery

Lori Setton (Biomedical Engineering) (https://engineering.wustl.edu/faculty/Lori-Setton.html)
Lucy and Stanley Lopata Distinguished Professor of Biomedical Engineering
PhD, Columbia University
Biomechanics for local drug delivery, tissue regeneration specific to the knee joints and spine

Matthew J. Silva (Orthopaedic Surgery) (http://www.orthoresearch.wustl.edu/content/Laboratories/2963/Matthew-Silva/Silva-Lab/Overview.aspx)
Julia and Walter R. Peterson Orthopaedic Research Professor
PhD, Massachusetts Institute of Technology
Biomechanics of age-related fractures and osteoporosis

Simon Tang (Orthopaedic Surgery and Biomedical Engineering) (http://www.orthoresearch.wustl.edu/content/Laboratories/3043/Simon-Tang/Tang-Lab/Overview.aspx)
PhD, Rensselaer Polytechnic Institute
Biological mechanisms

Senior Professors

Phillip L. Gould
PhD, Northwestern University
Structural analysis and design, shell analysis and design, biomechanical engineering

Kenneth L. Jerina (https://engineering.wustl.edu/faculty/Ken-Jerina.html)
DSc, Washington University
Materials, design, solid mechanics, fatigue, fracture

Shankar M.L. Sastry
PhD, University of Toronto
Materials science, physical metallurgy

Salvatore P. Sutera
PhD, California Institute of Technology
Viscous flow, biorheology

Barna A. Szabo
PhD, State University of New York at Buffalo
Numerical simulation of mechanical systems, finite-element methods

Senior Lecturer

Louis G. Woodhams (https://engineering.wustl.edu/faculty/Louis-Woodhams.html)
BS, University of Missouri–St. Louis
Computer-aided design

Lecturers

Chiamaka Asinugo (https://engineering.wustl.edu/faculty/Chiamaka-Asinugo.html)
MS, Washington University
Mechanical engineering design

Sharniece Holland (https://engineering.wustl.edu/faculty/Sharniece-Holland.html)
PhD, University of Alabama
Additive manufacturing, mathematics

Jeffery Krampf (https://engineering.wustl.edu/faculty/Jeff-Krampf.html)
MS, Washington University
Fluid mechanics, modeling, design

J. Jackson Potter (https://engineering.wustl.edu/faculty/Jackson-Potter.html)
PhD, Georgia Institute of Technology
Senior design

H. Shaun Sellers (https://engineering.wustl.edu/faculty/Shaun-Sellers.html)
PhD, Johns Hopkins University
Mechanics, materials

Adjunct Instructors

Ricardo L. Actis
DSc, Washington University
Finite element analysis, numerical simulation, aircraft structures

Robert G. Becnel
MS, Washington University
FE review

Andrew W. Cary
PhD, University of Michigan
Computational fluid dynamics

Richard S. Dyer
PhD, Washington University
Propulsion, thermodynamics, fluids

Timothy W. Jackson
PhD, University of Washington
Structural analysis, dynamics

Richard R. Janis
MS, Washington University
Building environmental systems

Gary D. Renieri
PhD, Virginia Polytechnic Institute and State University
Structural applications, composite materials

Krishnan K. Sankaran
PhD, Massachusetts Institute of Technology
Metallic materials

Michael C. Wendl
DSc, Washington University
Mathematical theory, computational methods in biology and engineering

Degree Requirements

Please visit the following pages for more information about Mechanical Engineering & Materials Science graduate programs:

- Doctoral Degrees (p. 94)
- Master of Science in Mechanical Engineering (MSME) (p. 94)
- Master of Science in Aerospace Engineering (MSAE) (p. 95)
- Master of Science (MS) in Materials Science and Engineering (p. 96)
- Master of Engineering (MEng) in Mechanical Engineering (p. 96)

Courses

Visit online course listings to view semester offerings for E37 MEMS (https://courses.wustl.edu/CourseInfo.aspx?sch=E&dept=E37&crslvl=5:8).

E37 MEMS 500 Independent Study
Independent investigation on topic of special interest. Prerequisites: graduate standing and permission of the department chair. Students must complete the Independent Study Approval Form available in the department office.
Credit variable, maximum 3 units.

E37 MEMS 5001 Optimization Methods in Engineering
Analytical methods in design. Topics include: mathematical methods, linear and nonlinear programming, optimality criteria, fully stressed techniques for the design of structures and machine components, topological optimization, search techniques and genetic algorithms. Knowledge of calculus and computer programming is expected.
Credit 3 units. EN: BME T, TU

E37 MEMS 501 Graduate Seminar
This is a required pass/fail course for master's and doctoral degrees. A passing grade is required for each semester of full-time enrollment. A passing grade is received by attendance at the weekly seminars.

E37 MEMS 5102 Materials Selection in Design
Analysis of the scientific bases of material behavior in the light of research contributions of the past 20 years. Development of a rational approach to the selection of materials to meet a wide range of design requirements for conventional and advanced applications. Although emphasis is placed on mechanical properties, acoustical, optical, thermal and other properties of interest in design are discussed.
Credit 3 units. EN: BME T, TU

E37 MEMS 5104 CAE-Driven Mechanical Design
An introduction to the use of computer-aided engineering (CAE) tools in the mechanical design process. Topics include: integrating engineering analysis throughout the process; multidisciplinary optimization; and computer-aided design directed toward new manufacturing processes.

Students will work with commercial and research software systems to complete several projects. Students should have experience and familiarity with a CAD tool, optimization and the finite element method. Prerequisite: MEMS 202 Computer-Aided Design or equivalent.
Credit 3 units. EN: BME T, TU

E37 MEMS 5301 Nonlinear Vibrations
In this course, students are introduced to concepts in nonlinear dynamics and vibration and application of these concepts to nonlinear engineering problems. Specific topics include: modeling of lumped and continuous nonlinear systems (strings, beams and plates); vibrations of buckled structures; perturbation and other approximate analytical methods; the use and limitations of local linearization; properties of nonlinear behavior, such as dimension and Lyapunov exponents; stability of limit cycles; bifurcations; chaos and chaotic vibrations; experimental methods and data analysis for nonlinear systems. Concepts are reinforced with a number of examples from recently published research. Applications include aeroelastic flutter, impact dynamics, machine-tool vibrations, cardiac arrhythmias and control of chaotic behavior.
Credit 3 units. EN: BME T, TU

E37 MEMS 5302 Theory of Vibrations
Analytical methods in vibrations. Topics include: Duhamel's integral, Laplace and Fourier transforms and Fourier series with applications to transient response, forced response and vibration isolation; Lagrange's equations for linear systems, discrete systems, degrees of freedom, reducible coordinates, holonomic constraints and virtual work; matrix methods and state variable approach with applications to frequencies and modes, stability and dynamic response in terms of real and complex modal expansions, dynamic response of continuous systems by theory of partial differential equations, Rayleigh-Ritz and Galerkin energy methods, finite difference and finite element algorithms.
Credit 3 units. EN: BME T, TU

E37 MEMS 5401 General Thermodynamics
General foundations of thermodynamics valid for small and large systems, and for equilibrium and nonequilibrium states. Topics include: definitions of state, work, energy, entropy, temperature, heat interaction and energy interaction. Applications to simple systems; phase rule; perfect and semi-perfect gas; bulk-flow systems; combustion, energy and entropy balances; availability analysis for thermo-mechanical power generation; and innovative energy-conversion schemes. Prerequisite: graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5402 Radiation Heat Transfer
Formulation of the governing equations of radiation heat transfer. Topics include: electromagnetic theory of radiation; properties of ideal and real surfaces; techniques for solutions of heat transfer between gray surfaces; radiation in absorbing, emitting and scattering media.
Credit 3 units. EN: BME T, TU

E37 MEMS 5403 Conduction and Convection Heat Transfer
This course examines heat conduction and convection through various fundamental problems that are constructed from the traditional conservation laws for mass, momentum and energy. Problems include the variable-area fin, the unsteady Dirichlet, Robbins and Rayleigh problems, multidimensional steady conduction, the Couette flow problem, duct convection and boundary layer convection. Though some numerics are discussed, emphasis is on mathematical technique and includes the extended power series method, similarity reduction, separation of variables, integral transforms, and approximate integral methods.
Credit 3 units. EN: BME T, TU

E37 MEMS 5404 Combustion Phenomena
This course provides an introduction to fundamental aspects of combustion phenomena, including relevant thermochemistry, fluid mechanics, and transport processes as well as the interactions among them. Emphasis is on elucidation of the physico-chemical processes, problem formulation and analytic techniques. Topics covered include non-premixed and premixed flames, deflagrations and detonations, particle combustion, flame extinction, flame synthesis, pollutant formation and methods of remediation. Contemporary topics associated with combustion are discussed throughout. Prerequisite: Senior or graduate standing or permission of instructor.
Same as E44 EECE 512
Credit 3 units. EN: BME T, TU

E37 MEMS 5410 Fluid Dynamics I
Formulation of the basic concepts and equations governing a Newtonian, viscous, conducting, compressible fluid. Topics include: transport coefficients and the elements of kinetic theory of gases, vorticity, incompressible potential flow; singular solutions; flow over bodies and lifting surfaces; similarity method; viscous flow, boundary layer, low Reynolds number flows, laminar and turbulent flows.
Credit 3 units. EN: BME T, TU

E37 MEMS 5411 Fluid Dynamics II
Governing equations and thermodynamics relations for compressible flow. Topics include: kinetic theory of gases; steady, one-dimensional flows with friction and heat transfer; shock waves; Rankine-Hugoniot relations; oblique shocks; reflections from walls and flow interfaces, expansion waves, Prandtl-Meyer flow, flow in nozzles, diffusers and inlets, two-and three-dimensional flows; perturbation methods; similarity rules; compressible laminar and turbulent boundary layers; acoustic phenomena. Emphasis is relevant to air vehicles.
Credit 3 units. EN: BME T, TU

E37 MEMS 5412 Computational Fluid Dynamics
Computational fluid dynamics relevant to engineering analysis and design. Topics include: fundamentals of finite-difference, finite-volume and finite-element methods; numerical algorithms for parabolic, elliptic and hyperbolic equations; convergence, stability and consistency of numerical algorithms; application of numerical algorithms to selected model equations relevant to fluid flow, grid-generation techniques and convergence acceleration schemes. Prerequisite: senior or graduate standing or permission of the instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5413 Advanced Computational Fluid Dynamics
Scope and impact of computational fluid dynamics. Governing equations of fluid mechanics and heat transfer. Three-dimensional grid-generation methods based on differential systems. Numerical methods for Euler and compressible Navier-Stokes equation. Numerical methods for incompressible Navier-Stokes equations. Computation of transonic inviscid and viscous flow past airfoils and wings. Analogy between the equations of computational fluid dynamics, computational electromagnetics, computational aeroacoustics and other equations of computational physics. Non-aerospace applications — bio-fluid mechanics, fluid mechanics of buildings, wind and water turbines, and other energy and environment applications. Prerequisite: MEMS 5412 or permission of the instructor.
Credit 3 units. EN: TU

E37 MEMS 5414 Aeroelasticity and Flow-Induced Vibrations
This course deals with the interactions between aerodynamics, dynamics and structures in aerospace systems. Topics covered include unsteady aerodynamics, finite-state aerodynamic models, classical fixed-wing flutter, rotary-wing aeroelasticity and experimental methods in aeroelasticity. Emphasis is given to the prediction of flutter and limit cycles in aeroelastic systems.
Credit 3 units. EN: TU

E37 MEMS 5417 Physical Acoustics
The primary focus of this course is on plane waves as an introduction to acoustical concepts of propagation, reflection and transmission, refraction, normal modes, horn theory, and absorption and dispersion. The course also includes more complicated problems (e.g., those involving spherical and cylindrical waves) and selected topics in applied acoustics including materials/damping, imaging, nondestructive evaluation, and acoustic microfluidics.
Credit 3 units.

E37 MEMS 5420 HVAC Analysis and Design I
Fundamentals of heating, ventilating, and air conditioning — moist air properties, the psychrometric chart, classic moist air processes, design procedures for heating and cooling systems. Design of HVAC systems for indoor environmental comfort, health, and energy efficiency. Heat transfer processes in buildings. Development and application of techniques for analysis of heating and cooling loads in buildings, including the use of commercial software. Course special topics can include LEED rating and certification, cleanrooms, aviation, aerospace, and naval applications, ventilation loads, animal control facilities, building automation control, and on-site campus tours of state-of-the-art building energy and environmental systems.
Credit 3 units. EN: BME T, TU

E37 MEMS 5421 HVAC Analysis and Design II
Fundamentals of heating, ventilating, and air conditioning — energy analysis and building simulation, design procedures for building water piping systems, centrifugal pump performance, design of building air duct systems, fan performance, optimum space air diffuser design for comfort, analysis of humidification and dehumidification systems, and advanced analysis of refrigeration systems. HVAC analytical techniques will include the use of commercial software. Course special topics can include LEED rating and certification, management for energy efficiency, energy auditing calculations, aviation, aerospace, and naval applications, ventilation loads, building automation control, and on-site campus tours of state-of-the-art building energy and environmental systems.
Credit 3 units. EN: BME T, TU

E37 MEMS 5422 Solar Thermal Energy Systems
Fundamentals of radiation heat transfers and solar radiation, including basic terminology, atmospheric scattering and absorption, radiation interactions with surfaces, and selective surfaces. Components, cycles, and materials of concentrating solar power plants, including parabolic trough and solar towers. Overview over thermal storage, other solar thermal technologies and photovoltaics. This course includes a final project. Prerequisite: MEMS 3420 or equivalent.
Credit 3 units. EN: BME T, TU

E37 MEMS 5423 Sustainable Environmental Building Systems
Sustainable design of building lighting and HVAC systems considering performance, life cycle cost and downstream environmental impact. Criteria, codes and standards for comfort, air quality, noise/vibration and illumination. Life cycle and other investment methods to integrate energy consumption/conservation, utility rates, initial cost, system/component longevity, maintenance cost and building productivity. Direct and secondary contributions to acid rain, global warming and ozone depletion.
Credit 3 units. EN: BME T, TU

E37 MEMS 5424 Thermo-Fluid Modeling of Renewable Energy Systems
Overview of sustainable energy systems. Fundamentals of energy conversion. Renewable energy sources and energy conversion from wind, biomass, solar-thermal, geothermal and ocean/waves. Applications to energy storage, fuel cells, green air and ground transportation, energy-efficient buildings. Energy-economics modeling, emissions modeling, global warming and climate change.
Credit 3 units. EN: BME T, TU

E37 MEMS 5425 Thermal Management of Electronics
As the demand for higher performance electronics continues its exponential growth, transistor density doubles every 18 to 24 months. Electronic devices with high transistor density generate heat and thus require thermal management to improve reliability and prevent premature failure. Demanding performance specifications result in increased package density, higher heat loads and novel thermal management technology. This course gives an overview of thermal management for micro/power electronics systems and helps engineers to develop a fundamental understanding of emerging thermal technologies. This course will include the following topics: background of electronics packaging; thermal design of heat sinks; single phase and multiphase flow in thermal systems; two-phase heat exchange devices for portable and high powered electronic systems; computational fluid dynamics for design of thermal systems. Prerequisites: senior or graduate standing.
Credit 3 units. EN: BME T, TU

E37 MEMS 5427 Fundamentals of Fuel Cells
This course is intended for the graduate and senior undergraduate Mechanical Engineering/ Materials Science/Chemical Engineering students interested in obtaining a fundamental background in fuel cell systems. Several types of fuel cells will be discussed, and the fundamental thermodynamics, kinetics of electrochemistry processes, and charge and mass transfer of fuel cells will be introduced. The primary focus will be placed on low temperature fuel cells based on polymer based electrolytes. The design, operation, performance, and reliability/durability of fuel cell systems will be discussed in detail. Specific interests to mechanical engineers, including water management and thermal management, will be a main focus of this course. Furthermore, the state of art research and development of fuel cell technologies may be presented through reading assignments from current literature.
Credit 3 units.

E37 MEMS 5500 Elasticity
Elastic constitutive relations for isotropic and anisotropic materials. Formulation of boundary-value problems. Application to torsion, flexure, plane stress, plane strain and generalized plane stress problems. Solution of three-dimensional problems in terms of displacement potentials and stress functions. Solution of two-dimensional problems using complex variables and conformal mapping techniques. Variational and minimum theorems.
Credit 3 units. EN: BME T, TU

E37 MEMS 5501 Mechanics of Continua
A broad survey of the general principles governing the mechanics of continuous media. Topics include general vector and tensor analysis, rigid body motions, deformation, stress and strain rate, large deformation theory, conservation laws of physics, constitutive relations, principles of continuum mechanics and thermodynamics, and two-dimensional continua. Prerequisite: ESE 501/502 or instructor's permission.
Credit 3 units. EN: BME T, TU

E37 MEMS 5502 Plates and Shells
Introduction to the linear theory of thin elastic plates and shells. The emphasis is on application and the development of physical intuition. The first part of the course focuses on the analysis of plates under various loading and support conditions. The remainder of the course deals mainly with axisymmetric deformation of shells of revolution. Asymptotic methods are used to solve the governing equations. Applications to pressure vessels, tanks, and domes. Prerequisites: BME 240 or MEMS 253; ESE 318 and ESE 319 or equivalent.
Credit 3 units. EN: BME T, TU

E37 MEMS 5506 Experimental Methods in Solid Mechanics
Current experimental methods to measure mechanical properties of materials are covered. Lectures include theoretical principles, measurement considerations, data acquisition and analysis techniques. Lectures are complemented by laboratory sections using research equipment such as biaxial testing machines, pressure myographs, indentation devices for different scales, and viscometers.
Credit 3 units. EN: BME T, TU

E37 MEMS 5507 Fatigue and Fracture Analysis
The course objective is to demonstrate practical methods for computing fatigue life of metallic structural components. The course covers the three major phases of metal fatigue progression: fatigue crack initiation, crack propagation and fracture. Topics include: stress vs. fatigue life analysis, cumulative fatigue damage, linear elastic fracture mechanics, stress intensity factors, damage tolerance analysis, fracture toughness, critical crack size computation and load history development. The course focus is on application of this technology to design against metal fatigue and to prevent structural failure.
Credit 3 units. EN: BME T, TU

E37 MEMS 5510 Finite Element Analysis
This course covers the theory and application of the finite element method. Topics include basic concepts, generalized formulations, construction of finite element spaces, extensions, shape functions, parametric mappings, numerical integration, mass matrices, stiffness matrices and load vectors, boundary conditions, modeling techniques, computation of stresses, stress resultants and natural frequencies, and control of the errors of approximation. Prerequisite: Graduate standing or permission of instructor.
Credit 3 units. EN: TU

E37 MEMS 5515 Numerical Simulation in Solid Mechanics I
The solution of 2D and 3D elasticity problems using the finite element method will be covered in this course. Topics include linear elasticity; laminated material; stress concentration; stress intensity factor; solution verification; J integral; energy release rate; residual stress; multi-body contact; nonlinear elasticity; plasticity; and buckling. Prerequisites: MEMS 424 or MEMS 5704; MEMS 5500 or MEMS 5501; and graduate standing or permission of instructor.
Credit 3 units.

E37 MEMS 5516 Numerical Simulation in Solid Mechanics II
The solution of 2D and 3D elasticity problems using the finite element method will be covered in this course. Topics include laminates and composite materials; nonlinear elasticity; plasticity; incremental theory of plasticity; residual stress; geometric nonlinearity; membrane and bending load coupling; multi-body contact; stress intensity factor; interference fit; and buckling analysis. Prerequisite: Graduate standing or permission of instructor.
Credit 3 units.

E37 MEMS 5520 Advanced Analytical Mechanics
Lagrange's equations and their applications to holonomic and non-holonomic systems will be covered in this course. Topics include reduction of degrees of freedom by first integrals, variational principles, Hamilton-Jacobi theory, general transformation theory of dynamics, applications such as theory of vibrations and stability of motion, and the use of mathematical principles to resolve nonlinear problems. Prerequisite: Senior or graduate standing or permission of instructor.
Credit 3 units. EN: TU

E37 MEMS 5560 Interfaces and Attachments in Natural and Engineered Structures
Attachment of dissimilar materials in engineering and surgical practice is a challenge. Bimaterial attachment sites are common locations for injury and mechanical failure. Nature presents several highly effective solutions to the challenge of bimaterial attachment that differ from those found in engineering practice. This course bridges the physiologic, surgical, and engineering approaches to connecting dissimilar materials. Topics covered in this course include natural bimaterial attachments; engineering principles underlying attachments; analysis of the biology of attachments in the body; mechanisms by which robust attachments are formed; concepts of attaching dissimilar materials in surgical practice and engineering; and bioengineering approaches to more effectively combine dissimilar materials.
Credit 3 units. EN: BME T, TU

E37 MEMS 5561 Mechanics of Cell Motility
A detailed review of biomechanical inputs that drive cell motility in diverse extracellular matrices (ECMs). This class discusses cytoskeletal machineries that generate and support forces, mechanical roles of cell-ECM adhesions, and regulation of ECM deformations. Also covered are key methods for cell level mechanical measurements, mathematical modeling of cell motility, and physiological and pathological implications of mechanics-driven cell motility in disease and development.
Credit 3 units.

E37 MEMS 5562 Cardiovascular Mechanics
This course focuses on solid and fluid mechanics in the cardiac and cardiovascular system. Cardiac and cardiovascular physiology and anatomy. Solid mechanics of the heart, heart valves, arteries, veins and microcirculation. Flow through the heart chambers and blood vessels. Prerequisites: graduate standing or permission of instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5564 Orthopaedic Biomechanics—Cartilage/Tendon
Basic and advanced viscoelasticity and finite strain analysis applied to the musculoskeletal system, with a primary focus on soft orthopaedic tissues (cartilage, tendon and ligament). Topics include: mechanical properties of cartilage, tendon and ligament; applied viscoelasticity theory for cartilage, tendon and ligament; cartilage, tendon and ligament biology; tendon and ligament wound healing;

osteoarthritis. This class is geared to graduate students and upper-level undergraduates familiar with statics and mechanics of deformable bodies. Prerequisites: BME 240 or equivalent. Note: BME 590Z (463/563) Orthopaedic Biomechanics—Bones and Joints is *not* a prerequisite.
Credit 3 units. EN: TU

E37 MEMS 5565 Mechanobiology of Cells and Matrices
At the interface of the cell and the extracellular matrix, mechanical forces regulate key cellular and molecular events that profoundly affect aspects of human health and disease. This course offers a detailed review of biomechanical inputs that drive cell behavior in physically diverse matrices. In particular, cytoskeletal force-generation machineries, mechanical roles of cell-cell and cell-matrix adhesions, and regulation of matrix deformations are discussed. Also covered are key methods for mechanical measurements and mathematical modeling of cellular response. Implications of matrix-dependent cell motility in cancer metastasis and embryonic development are discussed. Prerequisite: graduate standing or permission of the instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5566 Engineering Mechanobiology
Engineering Mechanobiology is a new paradigm for understanding and manipulating the biological function of plants, animals, and their cells. Mechanical force has emerged as a critical component of all biological systems, providing mechanisms to sculpt plants and animals during morphogenesis, to enable cell migration, polarization, proliferation, and differentiation in response to physical changes in the environment, and to modulate the function of single molecules. This course provides a foundation for understanding these factors across plant and animal cells. The course begins with an introduction to plant and animal cell biology and principles of signaling, then progresses to an overview of the cell wall and ECM and an introduction to the mechanics and statistical mechanics of solid, viscoelastic, and fibrous continua. The course then focuses on the questions of how do cells feel, how do cells converse with the ECM and wall, and how do cells remember? Knowledge of undergraduate calculus and physics is expected.
Credit 3 units. EN: TU

E37 MEMS 5601 Mechanical Behavior of Materials
A materials science-based study of mechanical behavior of materials with emphasis on mechanical behavior as affected by processes taking place at the microscopic and/or atomic level. The response of solids to external or internal forces as influenced by interatomic bonding, crystal/molecular structure, crystalline/noncrystalline defects and material microstructure are studied. The similarities and differences in the response of different kinds of materials viz., metals and alloys, ceramics, polymers and composites are discussed. Topics covered include physical basis of elastic, visco elastic and plastic deformation of solids; strengthening of crystalline materials; visco elastic deformation of polymers as influenced by molecular structure and morphology of amorphous, crystalline and fibrous polymers; deformation and fracture of composite materials; mechanisms of creep, fracture and fatigue; high strain-rate deformation of crystalline materials; and deformation of noncrystalline materials.
Credit 3 units. EN: BME T, TU

E37 MEMS 5602 Non-metallics
Structure, mechanical and physical properties of ceramics and cermets, with particular emphasis on the use of these materials for space, missile, rocket, high-speed aircraft, nuclear and solid-state applications.
Credit 3 units. EN: BME T, TU

E37 MEMS 5603 Materials Characterization Techniques I
An introduction to the basic theory and instrumentation used in transmission electron, scanning electron and optical microscopy. Practical laboratory experience in equipment operations, experimental procedures and material characterization.
Credit 3 units. EN: BME T, TU

E37 MEMS 5604 Materials Characterization Techniques II
Introduction to crystallography and elements of X-ray physics. Diffraction theory and application to materials science including following topics: reciprocal lattice concept, crystal-structure analysis, Laue methods, rotating crystal methods, powder method, and laboratory methods of crystal analysis.
Credit 3 units. EN: BME T, TU

E37 MEMS 5605 Mechanical Behavior of Composites
Analysis and mechanics of composite materials. Topics include micromechanics, laminated plate theory, hydrothermal behavior, creep, strength, failure modes, fracture toughness, fatigue, structural response, mechanics of processing, nondestructive evaluation, and test methods. Prerequisite: graduate standing or permission of the instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5606 Soft Nanomaterials
Soft nanomaterials, which range from self-assembled monolayers (SAMs) to complex 3D polymer structures, are gaining increased attention owing to their broad-range applications. The course introduces the fundamental aspects of nanotechnology pertained to soft matter. Various aspects related to the design, fabrication, characterization and application of soft nanomaterials are discussed. Topics covered include but are not limited to SAMs, polymer brushes, layer-by-layer assembly, responsive polymers structures (films, capsules), polymer nanocomposites, biomolecules as nanomaterials and soft lithography.
Credit 3 units. EN: BME T, TU

E37 MEMS 5607 Introduction to Polymer Blends and Composites
The course covers topics in multicomponent polymer systems (polymer blends and polymer composites) such as: phase separation and miscibility of polymer blends, surfaces and interfaces in composites, microstructure and mechanical behavior, rubber toughened plastics, thermoplastic elastomers, block copolymers, fiber reinforced and laminated composites, techniques of polymer processing with an emphasis on composites processing, melt processing methods such as injection molding and extrusion, solution processing of thin films, selection of suitable processing methods and materials selection criteria for specific applications. Advanced topics include: nanocomposites such as polymer/CNT composites, bioinspired nanocomposites, and current research challenges. Prerequisite: MEMS 3610 or equivalent or permission of instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5608 Introduction to Polymer Science and Engineering
Topics covered in this course are: the concept of long-chain or macromolecules, polymer chain structure and configuration, microstructure and mechanical (rheological) behavior, polymer phase transitions (glass transition, melting, crystallization), physical chemistry of polymer solutions (Flory-Huggins theory, solubility parameter, thermodynamics of mixing and phase separation), polymer surfaces and interfaces, overview of polymer processing (extrusion, injection molding, film formation, fiber spinning) and modern applications of synthetic and bio-polymers.
Credit 3 units. EN: BME T, TU

E37 MEMS 5610 Quantitative Materials Science & Engineering
This course will cover the mathematical foundation of primary concepts in materials science and engineering. Topics covered include mathematical techniques in materials science and engineering; Fourier series; ordinary and partial differential equations; special functions; matrix algebra; and vector calculus. Each topic will be followed by its application to concepts in thermodynamics; kinetics and phase transformations; structure and properties of hard and soft matter; and characterization techniques. This course is intended especially for students pursuing graduate study in materials science.
Credit 3 units. EN: BME T, TU

E37 MEMS 5611 Principles and Methods of Micro and Nanofabrication
A hands-on introduction to the fundamentals of micro- and nano-fabrication processes with emphasis on cleanroom practices. The physical principles of oxidation, optical lithography, thin film deposition, etching and metrology methods will be discussed, demonstrated and practiced. Students will be trained in cleanroom concepts and safety protocols. Sequential micro-fabrication processes involved in the manufacture of microelectronic and photonic devices will be shown. Training in imaging and characterization of micro- and nano-structures will be provided. Prerequisite: graduate or senior standing or permission of the instructor
Credit 3 units. EN: BME T, TU

E37 MEMS 5612 Atomistic Modeling of Materials
This course will provide a hands-on experience using atomic scale computational methods to model, understand and predict the properties of real materials. It will cover modeling using classical force-fields, quantum-mechanical electronic structure methods such as density functional theory, molecular dynamics simulations, and Monte Carlo methods. The basic background of these methods along with examples of their use for calculating properties of real materials will be covered in the lectures. Atomistic materials modeling codes will be used to calculate various material properties. Prerequisites: MEMS 3610 or equivalent or permission of instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5613 Biomaterials Processing
Biomaterials with 3D structures are important for tissue regeneration. The goal of this class is to introduce various types of biomaterials and fabrication approaches to create 3D structures. The relationship between material properties, processing methods, and design will be the primary focus. The topics include degradable biomaterials for scaffold fabrication, processing of tissue engineering scaffolds, processing of tissue engineering hydrogels, processing of drug delivery systems, and scaffold surface modification.
Credit 3 units. EN: BME T, TU

E37 MEMS 5614 Polymeric Materials Synthesis and Modification
Polymer is a class of widely used material. Polymer performance is highly dependent on its chemical properties. The goal of this class is to introduce methods for the synthesis and modification of polymers with different chemical properties. The topics include free radical polymerization, reversible addition-fragmentation chain transfer polymerization, atom transfer radical polymerization, step growth polymerization, cationic polymerization, anionic polymerization, ring-opening polymerization, and bulk and surface modification of polymers.
Credit 3 units. EN: BME T, TU

E37 MEMS 5615 Metallurgy and Design of Alloys
The design of materials used in critical structures (e.g., airplanes) entails optimizing and balancing multiple properties (e.g., strength, durability, corrosion resistance) to satisfy often conflicting requirements (e.g., better fuel efficiency, lower cost, operation in extreme conditions). Properties of metallic materials are determined by their "microstructure," which in turn is determined by their compositions and processing paths. An understanding of the multivariate relationships among compositions, processing parameters, microstructures, and properties is therefore essential to designing alloys and predicting their behavior in service. This course will discuss these relationships, with emphasis on the hierarchy of microstructural features, how they are achieved by processing, and how they interact to provide desirable property combinations -- essentially the physical metallurgy of alloys. This course will focus on high-performance alloys presently used in airframes as well as alloy design for state-of-the-art processes such as additive manufacturing. Prerequisite: MEMS 3610.
Credit 3 units. EN: BME T, TU

E37 MEMS 5616 Defects in Materials
Defects in materials play a critical role in controlling the properties of solids, which makes them interesting and necessary to study. The objective of this course is to provide a broad overview of defects in crystalline solids, their effect on properties, and methods of characterizing them. Course topics include crystal structures, defect classification, defect interactions, the role of defects in controlling properties of materials, and characterization techniques.
Credit 3 units. EN: BME T, TU

E37 MEMS 5617 Advanced Study of Solid-State Electronics
This course is designed for students who want to pursue advanced study in solid-state materials and electronic applications. It will provide fundamentals of 1) basic solid-state physics 2) phase equilibria and fabrication of emerging solid-state materials: 3D thin films (III-V, III-N, complex oxide) and low dimensional materials (0D, 1D, 2D) 3) electrical and photonic properties and 4) property manipulation: doping and strain engineering. Students will learn various emerging solid-state electronic devices such as HEMT, nano-materials based TFT, QD LEDs, nanogenerators, advanced solar cells and more. The goal of this course is to help students understand fundamentals to design new solid-state device architectures. The course is particularly beneficial for students who have an interest in the emerging semiconductor field.
Credit 3 units. EN: BME T, TU

E37 MEMS 5618 Electronic Behavior of Materials
This course is designed for students who want to understand electronic behavior of materials which is related to electronic/semiconductor research and industry. It will provide fundamentals of 1) crystal structures and bonding of electronic materials, 2) electronic movement in various materials, 3) electronic behavior in junctions, 4) electronic, optic, and magnetic properties correlation, 5) various electronic applications such as solar cells, light-emitting diodes, and transistors. The goal of the course is to help students understand basic knowledge and fundamental about electronic behavior in materials. The course is particularly beneficial for students who have an interest in the semiconductor research and industry.
Credit 3 units.

E37 MEMS 5619 Thermodynamics of Materials
Thermodynamics of mixtures and phase equilibria in materials systems. The course will review the laws of thermodynamics and introduce the principles of statistical mechanics along with thermodynamic variables and the relationships between them. It will cover thermodynamic

equilibria in unary and multicomponent systems along with the construction of phase diagrams. The use of thermodynamics for understanding surfaces and interfaces, defects, chemical reactions, and other technical applications will be emphasized.
Credit 3 units.

E37 MEMS 5700 Aerodynamics
This course introduces fundamental concepts of aerodynamics, equations of compressible flows, irrotational flows and potential flow theory, singularity solutions, circulation and vorticity, the Kutta-Joukowski theorem, thin airfoil theory, finite wing theory, slender body theory, subsonic compressible flow and the Prandtl-Glauert rule, supersonic thin airfoil theory, an introduction to performance, and basic concepts of airfoil design. Prerequisite: MEMS 3410 or permission of instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5701 Aerospace Propulsion
Propeller, jet, ramjet and rocket propulsion. Topics include: fundamentals of propulsion systems, gas turbine engines, thermodynamics and compressible flow, one-dimensional gas dynamics, analysis of engine performance, air breathing propulsion system, the analysis and design of engine components, and the fundamentals of ramjet and rocket propulsion.
Credit 3 units. EN: BME T, TU

E37 MEMS 5703 Analysis of Rotary-Wing Systems
This course introduces the basic physical principles that govern the dynamics and aerodynamics of helicopters, fans and wind turbines. Simplified equations are developed to illustrate these principles, and the student is introduced to the fundamental analysis tools required for their solution. Topics include: harmonic balance, Floquet theory and perturbation methods.
Credit 3 units. EN: BME T, TU

E37 MEMS 5704 Aircraft Structures
Basic elements of the theory of elasticity; application to torsion of prismatic bars with open and closed thin-wall sections; the membrane analogy; the principle of virtual work applied to 2D elasticity problems. Bending, shear and torsion of open and closed thin-wall section beams; principles of stressed skin construction, structural idealization for the stress analysis of wings, ribs and fuselage structures. Margin of safety of fastened connections and fittings. Stability of plates, thin-wall section columns and stiffened panels. Application of the finite element method for the analysis of fastened connections, structural fittings and problems of local stability of aircraft structural components.
Credit 3 units.

E37 MEMS 5705 Wind Energy Systems
A comprehensive introduction to wind energy systems, a practical means of extracting green and sustainable energy. Topics include: a historical perspective of wind turbines; horizontal axis and vertical axis wind turbines; the basic parameters such as power rating and efficiency; the structural components ranging from blade and hub to nacelle and tower; wind turbine aerodynamics, aeroelasticity and control systems; blade fatigue; statistical wind modeling; unsteady airfoil aerodynamics and downstream wake; and environmental considerations such as noise and aesthetics. Prerequisite: senior or graduate standing in engineering or permission of the instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5706 Aircraft Performance
This course introduces the principles and applications of aerodynamics to determine the performance of typical jet engine and propeller airplanes. The performance calculations include flight conditions of takeoff, climb, level flight, and landing. The topics covered also include range and endurance computation, turning flight, flight envelope, constraint analysis and design process. The knowledge and skill gained in this course can be readily applied in the preliminary design of an airplane. Prerequisite: senior or graduate standing in engineering, or permission of the instructor.
Credit 3 units. EN: BME T, TU

E37 MEMS 5707 Flight Dynamics
The course objective is to introduce methods for analyzing and simulating flight vehicle dynamics and to assess performance characteristics. Topics will include: aerodynamics, structural dynamics, vehicle forces and moments, vehicle equations of motion, rigid body and flexible body considerations, model linearization, longitudinal and lateral stability, stability and control augmentation, and aircraft handling qualities. The course focus is on the application of flight dynamics principles and MATLAB will be used extensively for modeling and simulation assignments and demonstrations.
Credit 3 units. EN: TU

E37 MEMS 5801 Micro-Electro-Mechanical Systems I
Introduction to MEMS: Microelectromechanical systems (MEMS) are ubiquitous in chemical, biomedical and industrial (e.g., automotive, aerospace, printing) applications. This course covers important topics in MEMS design, micro-/nanofabrication, and their implementation in real-world devices. The course includes discussion of fabrication and measurement technologies (e.g., physical/chemical deposition, lithography, wet/dry etching, and packaging), as well as application of MEMS theory to design/fabrication of devices in a cleanroom. Lectures cover specific processes and how those processes enable the structures needed for accelerometers, gyros, FR filters, digital mirrors, microfluidics, micro total-analysis systems, biomedical implants, etc. The laboratory component allows students to investigate those processes first-hand by fabricating simple MEMS devices.
Credit 3 units. EN: BME T, TU

E37 MEMS 5912 Biomechanics Journal Club
This journal club is intended for graduate students and advanced undergraduates with an interest in biomechanics. We review landmark and recent publications in areas such as brain, cardiovascular and orthopedic biomechanics, discussing both experimental and modeling approaches. This course meets once weekly at a time to be arranged.
Credit 1 unit. EN: TU

E37 MEMS 597 MEMS Research Rotation
Independent research project that will be determined jointly by the doctoral student and the instructor. Assignments may include background reading, presentations, experiments, theoretical, and/or modeling work. The goal of the course is for the doctoral student to learn the background, principles and techniques associated with research topics of interest and to determine a mutual fit for the student's eventual doctoral thesis laboratory.
Credit 3 units.

E37 MEMS 598 Energy Analysis and Design Project
The Energy Analysis and Design Project is designed to provide mechanical engineering skills in energy applications, renewable energy, and technologies related to energy which can involve heat transfer, thermodynamics, and fluid mechanics. The project topic can be chosen by the student or can be developed by both the student and faculty sponsor. The subsequent research and analysis, conducted under

the guidance and direction of the faculty sponsor, results in a final project report that is approved by the faculty sponsor. The course is normally completed over one or two semesters. Recent projects have included: Energy Modeling and Efficiency Improvements: A Comparison of TRACE 700 and eQuest, Analysis of Hydroelectric Power, Optimization of Residential Solar Thermal Heating in the United States, Analysis of Ocean Thermal Energy Conversion Systems, Laboratory Plug Load Analysis and Case Study, Modeling and Optimizing Hydronic Radiant Heating and Cooling Systems using Comsol Multiphysics, CFD Analysis in HVAC Applications, Energy Analysis of Waste Disposal Methods, CFD Analysis of Containment Solutions for Data Center Cooling, Energy Recovery Ventilation, Comparative Study of Green Building Rating Systems, Grid Energy Storage, Protection of Permafrost Under the Quinghai-Tibet Railway by Heat Pipe Technology, Investing in Residential Solar Photovoltaic Systems, How Piping Layout Effects Energy Usage, and Comparison of Building Energy Savings Between China and the United States.
Credit variable, maximum 3 units.

E37 MEMS 599 Master's Research
Credit variable, maximum 6 units.

E37 MEMS 600 Doctoral Research
Credit variable, maximum 9 units.

Doctoral Degrees

Policies & Regulations

A key objective of the doctoral program is to promote cutting-edge multidisciplinary research and education in the areas of mechanical engineering and materials science. Students are selected for admission to the program by a competitive process, and they typically start in the fall semester. On arriving at Washington University in St. Louis, the student will be advised by the Director of Graduate Studies on all procedural issues. The student will choose a faculty advisor by the end of the first year of residency in the program.

Summary of Requirements for Doctoral Students

The following is a brief summary of the requirements for students in the Mechanical Engineering & Materials Science doctoral programs:

1. Pass the qualifying exams. Qualifying exams should be taken by the end of the first year.
2. Prepare and defend a research proposal. The research proposal should be defended by the end of the third year.
3. Write and successfully defend the doctoral dissertation.
4. Complete a minimum of 36 units of course credit and a minimum of 24 units of doctoral research; a total of 72 credit units is required to earn the PhD degree.
5. Satisfy the general teaching requirement as specified by the department. (There is no teaching requirement for the DSc.)

Degrees Offered

The Department of Mechanical Engineering & Materials Science (MEMS) offers the following doctoral degrees:

- PhD in Mechanical Engineering
- PhD in Aerospace Engineering
- DSc in Mechanical Engineering, Aerospace Engineering, or Materials Science

  The requirements for the DSc in Mechanical Engineering, Aerospace Engineering, or Materials Science and Engineering are identical to those for the PhD except for the following: (1) the mentored teaching experience is not required for the DSc; (2) the residency requirement for the DSc is limited to 24 units completed at Washington University; and (3) the requirements for research rotations and the time limits for the completion of the qualifying exam, proposal, and thesis defense for the PhD do not apply to the DSc. The DSc is recommended for students who will pursue doctoral studies part-time. Stipend support from grants or contracts is typically not available to DSc candidates.
- Students may also pursue a PhD in Materials Science — through the Institute of Materials Science & Engineering (IMSE) — while working with professors from the Department of Mechanical Engineering & Materials Science. For details about this program, visit the IMSE Graduate Program (http://imse.wustl.edu/graduate-program/) webpage.

For more information about MEMS PhD degrees, visit the MEMS Graduate Programs (https://mems.wustl.edu/graduate/programs/Pages/default.aspx) webpage.

Master of Science in Mechanical Engineering (MSME)

Thesis Option

The quantitative requirement for the degree is 30 credit units. A minimum of 24 of these units must be course work, and a minimum of 6 units must be Master's Research (MEMS 599).

The overall grade-point average must be 2.70 or better.

Courses may be chosen from 400- and 500-level offerings. All must be engineering, math or science courses with the following restrictions:

- A maximum of 3 units of Independent Study (MEMS 500) are allowed.
- A maximum of 6 units of 400-level courses are allowed, and these must be from courses not required for the BSME degree (if counted for the MSAE) or not required for the BSAE degree (if counted for the MSME degree), with the exception of MEMS 4301 Modeling, Simulation and Control, which can count toward the MS.
- Each course must be approved by the candidate's thesis advisor.

- A maximum of 6 units of transfer credit with a grade of B or better are allowed for courses taken at other graduate institutions.
- A minimum of 15 units of the total 30 units must be in MEMS courses.

The student must also write a satisfactory thesis and successfully defend it in an oral examination before a faculty committee consisting of at least three members, at least two of which are from the Department of Mechanical Engineering & Materials Science.

Full-time MS students in any area are required every semester to take MEMS 501 Graduate Seminar, which is a zero-unit, pass/fail course.

Course Option

The quantitative requirement for the degree is 30 credit units (normally 10 courses) completed with a grade-point average of 2.70 or better.

Course programs may be composed from one area of specialization below (MSME) or from aerospace engineering (MSAE). They must conform to the following distribution:

Applied Mathematics	6 credits
Area of Specialization	15 credits
Electives	9 credits

Elective courses may be chosen in any area of engineering or mathematics at the 400 level or higher. Of the 30 units, a minimum of 24 must be in 500-level courses. No more than 6 units may be in 400-level courses; core requirements for the ME undergraduate degree are not allowed, with the exception of MEMS 4301, which is allowed. A maximum of 3 credits of independent study (MEMS 400 or MEMS 500) may be used as an elective. A minimum of 15 units must be in MEMS. Non-engineering courses (e.g., T courses, finance or entrepreneurship courses) cannot be counted.

Full-time MS students in any area are required every semester to take MEMS 501 Graduate Seminar, which is a zero-unit, pass/fail course.

Degree candidates will plan their course programs with the help of a departmental advisor. Use the links below to find courses in the areas of specialization.

Engineering Areas of Specialization for the MS in Mechanical Engineering

- Applied Mechanics (https://wustl.app.box.com/s/40dacfdykkxmb9z7t9x801t14ore6wat/)
- Dynamics/Mechanical Design (https://wustl.app.box.com/s/40dacfdykkxmb9z7t9x801t14ore6wat/)
- Solid Mechanics/Materials Science (https://wustl.app.box.com/s/40dacfdykkxmb9z7t9x801t14ore6wat/)
- Fluid/Thermal Sciences (https://wustl.app.box.com/s/40dacfdykkxmb9z7t9x801t14ore6wat/)
- Energy Conversion and Efficiency (https://mems.wustl.edu/graduate/programs/Pages/specialized-tracks.aspx)

Master of Science in Aerospace Engineering (MSAE)

Thesis Option

The quantitative requirement for the degree is 30 credit units. A minimum of 24 of these units must be course work, and a minimum of 6 units must be Master's Research (MEMS 599).

The overall grade-point average must be 2.70 or better.

Courses may be chosen from 400- and 500-level offerings. All must be engineering, math or science courses with the following restrictions:

- A maximum of 3 units of Independent Study (MEMS 500) are allowed.
- A maximum of 6 units of 400-level courses are allowed, and these must be from courses not required for the BSME degree (if counted for the MSAE) or not required for the BSAE degree (if counted for the MSME degree), with the exception of MEMS 4301, which is allowed.
- Each course must be approved by the candidate's thesis advisor.
- A maximum of 6 units of transfer credit with a grade of B or better are allowed for courses taken at other graduate institutions.
- A minimum of 15 units of the total 30 units must be in MEMS courses.

The student must also write a satisfactory thesis and successfully defend it in an oral examination before a faculty committee consisting of at least three members, at least two of which are from the Department of Mechanical Engineering & Materials Science.

Full-time MS students in any area are required every semester to take MEMS 501 Graduate Seminar, which is a zero-unit, pass/fail course.

Course Option

The quantitative requirement for the degree is 30 credit units (normally 10 courses) completed with a grade-point average of 2.70 or better.

Course programs must be focused in the area of aerospace engineering. They must conform to the following distribution:

Applied Mathematics	6 credits
Aerospace	15 credits
Electives	9 credits

Elective courses may be used to accumulate additional credits in other areas of engineering or in mathematics. A maximum of 3 credits of Independent Study (MEMS 500) may be included as an elective course. A maximum of 6 units of 400-level courses are allowed for the MSME or MSAE degree, and these must be from courses not required for the BSME degree — with the exception of MEMS 4301, which is allowed. Non-engineering courses (e.g., T-courses, finance or entrepreneurship courses) cannot be counted as engineering electives. A minimum of 15 units must be in MEMS.

Full-time MS students are required to take MEMS 501 Graduate Seminar, which is a zero-unit, pass/fail course.

Degree candidates will plan their course programs with the help of a departmental advisor.

Master of Science (MS) in Materials Science and Engineering

Thesis Option

The quantitative requirement for the degree is 30 credit units. A minimum of 24 of these units must be course credit, and a minimum of 6 units must be Master's Research (MEMS 599). A minimum of 15 units of the total 30 units must be in MEMS courses.

The overall grade-point average must be 2.70 or better.

Every semester, full-time MS students in Materials Science and Engineering (MSE) are required to take either the department's Graduate Seminar (MEMS 501) or the Graduate Seminar offered by the Institute of Materials Science & Engineering (IMSE 501). These are zero-unit, pass/fail courses.

Degree candidates will plan their programs with the help of their thesis advisor. Courses are to be Engineering courses at the 500 level or above or Chemistry, Earth and Planetary Science, or Physics courses at the 400 level or above. Course credit must include at least 12 units (four courses) from a list of approved materials-focused courses (PDF) (http://bulletin.wustl.edu/grad/engineering/mechanical-engineering-materials-science/ms-materials/Course_Options_for_MS_in_Materials_Science_081423.pdf) as well as 3 units (one course) of mathematics at the graduate level. The following restrictions apply:

- A maximum of 3 units of Independent Study (MEMS 500) are allowed.
- A maximum of 6 units of 400-level courses are allowed.
- Each course must be approved by the candidate's thesis advisor.
- A maximum of 6 units of transfer credit with a grade of B or better are allowed for courses taken at other graduate institutions.
- For the combined bachelor's/master's program (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/bachelors-masters.aspx), up to 6 units can count for both the BS and the MS, as long as the program of study satisfies the criteria above.

The student must also write a satisfactory thesis and successfully defend it in an oral examination before a faculty committee consisting of at least three members, at least two of which are from the Department of Mechanical Engineering & Materials Science.

Course Option

The quantitative requirement for the degree is 30 credit units (normally 10 courses). A minimum of 15 units of the total 30 must be in MEMS courses.

The overall grade-point average must be 2.70 or better.

Every semester, full-time MSE students are required to take either the department's Graduate Seminar (MEMS 501) or the Graduate Seminar offered by the Institute of Materials Science & Engineering (IMSE 501). These are zero-unit, pass/fail courses.

Degree candidates will plan their programs with the help of their faculty advisor. Courses are to be Engineering courses at the 500 level or above or Chemistry, Earth and Planetary Science, or Physics courses at the 400 level or above. Course credit must include at least 18 units (six courses) from a list of approved materials-focused courses (PDF) (http://bulletin.wustl.edu/grad/engineering/mechanical-engineering-materials-science/ms-materials/Course_Options_for_MS_in_Materials_Science_081423.pdf) as well as 3 units (one course) of mathematics at the graduate level. The following restrictions apply:

- A maximum of 3 units of Independent Study (MEMS 500) are allowed.
- A maximum of 6 units of 400-level courses are allowed.
- A maximum of 6 units of transfer credit with a grade of B or better are allowed for courses taken at other graduate institutions.
- For the combined bachelor's/master's program (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/bachelors-masters.aspx), up to 6 units can count for both the BS and the MS, as long as the program of study satisfies the criteria above.

The remaining courses (electives) may be chosen according to the general criteria above, as long as they contribute to a coherent program of study in materials science.

Master of Engineering (MEng) in Mechanical Engineering

The Master of Engineering in Mechanical Engineering (MEng in ME) is a one- to two-year program offered by the Department of Mechanical Engineering & Materials Science of Washington University in St. Louis. The program is especially tailored for (1) individuals without an ME or AE degree who plan to change careers and enter the ME profession; (2) international students seeking to establish U.S. credentials in the ME profession; and (3) current professionals working in ME who wish to advance their skills and education. A distinctive feature of the program is the ability to customize the course content to meet specific individual needs.

Degree requirements are as follows:

Candidates for admission should have an undergraduate degree in engineering, the physical sciences or mathematics, with a grade-point average of 2.75 or better.

It should be emphasized that, in many states, the MEng in ME will not be sufficient to qualify the degree recipient to sit for a professional engineering exam.

- 30 units of credit in engineering or mathematics courses are required, and these must be at the 400 level or higher. Courses from the other engineering departments (CSE, EECE, ESE and BME) are encouraged, but at least 15 of the 30 units must be in MEMS. Washington University Continuing Education Courses (i.e., the T courses or the U courses) are not permitted.
- All courses must be taken for a grade, with an overall GPA of 2.70 or higher required.
- At least 9 of the 30 units must be in MEMS courses at the 500 level.
- All 400-level courses must be either (1) approved for the Master of Science in Mechanical Engineering (ME) or Aerospace Engineering (AE) or (2) approved by the MEMS faculty for application toward the MEng degree.
- No more than 6 units of independent study are allowed.
- No more than 6 units may be transferred from another university. These units must be in engineering or math courses at the 400 level or above with a grade of B or better, and the courses must not be required for the candidate's BS degree.

Full-time MS students in any area are required to take MEMS 501 Graduate Seminar every semester. This is a zero-unit, pass/fail course.

Henry Edwin Sever Institute

With the Sever Institute's flexible schedules, both new and experienced professionals can keep their careers moving forward while developing the knowledge and credentials that will set them apart. Our graduate students seek to lead the way in making an impact on the wide range of organizational and technical opportunities and challenges in engineering, information technology, cybersecurity, construction, and complex operational environments. The experientially-driven curriculum and course work will increase students' knowledge and expertise. Those who complete our programs are prepared to step into leadership roles and make a real difference in both their organizations and the world.

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Online Degree Programs

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Graduate Certificates

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Online Graduate Certificates

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Email:	sever@wustl.edu
Website:	https://sever.wustl.edu

Degree Programs

Master of Construction Management

The Master of Construction Management (MCM) is a 30-unit program designed for working professionals. Students will be prepared for every aspect of leading a construction project or organization. Created for any professional of the built environment, our curriculum incorporates traditional themes like cost, time, risk and quality management with multidisciplinary topics such as business, finance, ethics and law. Lecture and lab-based education provides students with an environment for practical application utilizing best practices that address current issues and developments in the industry.

Part-time Master's Degree: 30 units, 2.5 years+ to complete

The Master of Construction Management/Master of Architecture (MCM/MArch) dual-degree program prepares architectural students for the diverse roles within today's multidisciplinary design/construction process. Sam Fox School of Design & Visual Arts architecture students can earn an MArch degree and an MCM degree in considerably less time than they would need to pursue each degree separately. More information can be found on the Master of Construction Management/Master of Architecture (MCM/MArch) dual-degree program page (https://sever.wustl.edu/degree-programs/construction/Architecture-Joint-Degree-Program.html) of the Sever Institute website.

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/construction/index.html

Faculty

Program Director

Steve Bannes
Director of Graduate Studies, Construction Management
Professor of Practice
MS, Education, Southwest Baptist University
BS, Construction Engineering & Management, Southern Illinois University Edwardsville

For a list of our program faculty (https://sever.wustl.edu/faculty/#construction_management), please visit our website.

Requirements

Master of Construction Management

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
Required: 18 units		
CNST 523A	Construction Cost Estimating	3
CNST 572	Legal Aspects of Construction	3
CNST 573	Fundamentals in Construction Management	3
CNST 574C	Construction Project Planning and Scheduling	3
CNST 579	Advanced Construction Management	3
ETEM 587	Communication Excellence for Influential Leadership	3
Electives: Choose 12 units		
Technology		
CNST 580B	Digital Construction Technology	3
CYBER 559	Introduction to Cybersecurity	3
ETEM 510	Understanding Emerging & Disruptive Technologies	3
INFO 506	Fundamentals of Information Technology	3
INFO 575	Enterprise Data Management	3
Project Management		
ARCH 447A	Structures I	3
ARCH 448A	Structures II	3
CNST 550D	Heavy Civil Construction Management	3
ETEM 531	Intro to Agile Project Management	3
ETEM 532	The Art & Science of Risk Management	3
Leadership		
ETEM 581	Leading in a Technology-Rich World	3
ETEM 582	Human Performance in the Organization	3
ETEM 586	Cross-Cultural Negotiation	3

Master of Construction Management/Master of Architecture (Dual Degree Program)

Total units required: 30 (21 McKelvey School of Engineering units and 9 units of A46 Architecture courses)

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
Required: 9 units MCM-MArch shared		
CNST 523A	Construction Cost Estimating *	3
CNST 573	Fundamentals in Construction Management *	3
CNST 574C	Construction Project Planning and Scheduling *	3
+12 Required MCM units		
ETEM 587	Communication Excellence for Influential Leadership	3
CNST 572	Legal Aspects of Construction	3
CNST 581A	MCM - M.Arch Capstone Project Phase 1	1
CNST 581B	MCM - M.Arch Capstone Project Phase 2	2
Elective: 3 units, choose from list below		3
Elective: Choose one course for 3 units		
Technology		
CNST 580B	Digital Construction Technology	3
CYBER 559	Introduction to Cybersecurity	3
ETEM 510	Understanding Emerging & Disruptive Technologies	3
INFO 506	Fundamentals of Information Technology	3
INFO 575	Enterprise Data Management	3
Project Management		
CNST 550D	Heavy Civil Construction Management	3
ETEM 531	Intro to Agile Project Management	3
ETEM 532	The Art & Science of Risk Management	3
Leadership		
ETEM 581	Leading in a Technology-Rich World	3
ETEM 582	Human Performance in the Organization	3
ETEM 586	Cross-Cultural Negotiation	3
Plus 9 units from Master of Architecture		**9**
MArch waived courses cannot be applied		

* These courses are covered by Arch funding and should be taken earlier in the joint program.

Courses

Visit online course listings to view semester offerings for T64 CNST (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T64&crslvl=5:8).

T64 CNST 523A Construction Cost Estimating
Construction cost estimating explores the application of cost estimating principles and estimating within a project management framework in conjunction with scope definition, quality control, planning and scheduling, risk management and loss prevention techniques, local conditions, information and communication, and working relations with stakeholders. Using a single building project, the course introduces the application of basic quantity surveying and estimating principles using a methodical approach with suggested check lists and techniques for arriving at a reliable cost estimate including direct, indirect, and contingency costs and profits. Student's estimating efforts culminate with a competitive bid day scenario. Prerequisite: T64 573 or permission of instructor.
Credit 3 units.

T64 CNST 550D Heavy Civil Construction Management
This course provides a broad perspective of the means, methods, and procedures associated with managing civil engineering and heavy construction projects. Topics include strategic bidding and estimating, heavy equipment, marine construction heavy civil operations and bridge building. Integration of scheduling, estimating, and construction contracts with a project based approach. Prerequisite: T64 573 or permission of instructor.
Credit 3 units.

T64 CNST 572 Legal Aspects of Construction
A survey of the legal problems of the construction manager, including but not limited to liability in the areas of contracts, agency, torts, insurance, bad judgment and oversight.
Credit 3 units.

T64 CNST 573 Fundamentals in Construction Management
In this course, students will be exposed to the overall construction process from initial concept through startup of the completed facility. The focus is to provide familiarization of the construction and contracting process and potential involvements by construction managers in the planning, design, construction, and post construction phases. Additional topics are introduced to provide a foundation which will prepare students for future construction management coursework. Case studies and industry examples are used throughout the course to authenticate the lectures and assignments.
Credit 3 units.

T64 CNST 574C Construction Project Planning and Scheduling
Project planning and scheduling process utilizing current techniques including critical path analysis for effective and logical scheduling of construction projects. Identification of project activities and their relationships; schedule development, analysis, and updating; relationship of project costs and resources to the schedule; legal implications; effective communication of schedule information; development of procedures to monitor actual field progress; computer application in project scheduling. Prereqs: T64 CNST 573 or permission of instructor.
Credit 3 units.

T64 CNST 579 Advanced Construction Management
A comprehensive study of the operations encountered in the management of a construction firm. Topics include estimating, scheduling, forms of contracts, risk analysis and management, extra work orders, claims and disputes, construction safety, and contract close-out. Prerequisite: T64 573, T64 574, T64 523A, or permission of the program director.
Credit 3 units.

T64 CNST 580B Digital Construction Technology
This course focuses on BIM's philosophy of integration between designers, construction professional, and owners, in order to overcome both technological and implementation changes using Virtual Design and Construction (VDC) and Integrated Project Delivery (IDP). VDC is a methodology that relies on a multidisciplinary collaboration of the digital simulation of design & construction. IPD, on the other hand, integrates people, systems, business structures and practices into a process to optimize efficiency and productivity. In this course, students will learn about BIM's application by exploring 3D, 4D aspects of BIM including geometry, spatial relationships, quantity take off, estimation and scheduling. Along with that, students also will learn about Virtual Design and Construction (VDC) and Integrated Project Delivery (IPD) system that are integral component of a successful BIM projects. Prerequisite: T64 573 or permission of instructor.
Credit 3 units.

T64 CNST 581A MCM - M.Arch Capstone Project Phase 1
This capstone course allows MCM/MArch joint-degree program students to apply constructability principles to their MArch degree projects (A46 ARCH 616) and to successfully demonstrate how they have applied those principles. Constructability principles include analysis of the construction methods and procedures, project cost, time, value, quality, and safety. Phase 1 is to be taken simultaneously with A46 ARCH 616 Degree Project. Phase 1 students will develop a constructability review, analysis, and plan for their individual project. Prerequisites: Admission to the MCM/MArch joint-degree program, T64 573, T64 523A, and T64 574C.
Credit 1 unit.

T64 CNST 581B MCM - M.Arch Capstone Project Phase 2
This capstone course allows MCM/MArch joint-degree program students to apply constructability principles to their MArch degree projects (A46 ARCH 616) and to successfully demonstrate how they have applied those principles. Constructability principles include analysis of the construction methods and procedures, project cost, time, value, quality, and safety. Phase 2 is to be taken after completing A46 ARCH 616 Degree Project. Phase 2 students will execute the constructability plan developed in Phase 1 and prepare and present the deliverables. Pre/Corequisite: T64 581A.
Credit 2 units.

Master of Cybersecurity Management

Securing an organization's data requires a combination of technical skills, innovative concepts and managerial acumen. The Master of Cybersecurity Management at Washington University is a 30-unit part-time program designed for working professionals. This program was developed with one critical goal: to educate professionals about how to manage the people and resources required to perform these tasks and to lead the cybersecurity functions of various organizations.

The curriculum provides students with the knowledge needed to protect from, defend against, respond to and recover after cyber threats. Graduates of this program will be equipped to design, engineer and assess global cybersecurity problems while maintaining the vision and strategy of the enterprise.

Part-time Master's Degree: 30 units, 2.5 years+ to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/cybersecurity/index.html

Faculty

Program Director

Joe Scherrer (https://sever.wustl.edu/faculty/Pages/Joe-Scherrer.aspx)
Executive Director, Professional Education
Director, Cybersecurity Strategic Initiative
Program Director, Graduate Studies in Cybersecurity Management
Doctor of Liberal Arts, Washington University in St. Louis, 2023 (projected)
MS, Business Administration, Boston University
MS, Information Systems Management, Air Force Institute of Technology
MS, National Security Studies, Naval War College
MS, Strategic Studies, Air War College
BS, Electrical Engineering, Washington University in St. Louis

For a list of our program faculty (https://sever.wustl.edu/faculty/#cybersecurity_management), please visit our website.

Requirements

Master of Cybersecurity Management

Total units required: 30

In order to earn the degree/certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree/certificate.

Code	Title	Units
Required: 21 units		
CYBER 560	Cybersecurity Technical Fundamentals	3
CYBER 561	Oversight for Excellence: Cybersecurity Management and Governance	3
CYBER 562	Efficient and Effective Cybersecurity Operations	3
CYBER 566	Cybersecurity Risk Management	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3
CYBER 587	Cloud Security	3
INFO 570	Leadership Seminar for Technology Professionals	3
Electives: Choose 9 units		
Cybersecurity Management Emphasis		
CYBER 563	Enterprise Network Security	3
CYBER 564	Access Control and Identity Management	3
CYBER 565	Cybersecurity Analytics	3
CYBER 568	Emerging Issues and Technology in Cybersecurity	3
CYBER 569	Incident Response and Business Continuity	3
CYBER 570	Managerial and Technical Approaches to Cybersecurity Assurance	3
Cybersecurity Design & Engineering Emphasis		
Offered through the Computer Science & Engineering department for those with the appropriate STEM background		
CSE 433S	Introduction to Computer Security	3
CSE 523S	Systems Security	3
CSE 569S	Recent Advances in Computer Security and Privacy	3
CSE 571S	Network Security	3
CSE 637S	Software Security	3
Bridge Course*		
CYBER 559	Introduction to Cybersecurity	3

* The bridge course is offered for students with limited to no cybersecurity background. The successfully completed course will count toward the 9 required elective units.

Courses

Visit online course listings to view semester offerings for T83 CYBER (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T83&crslvl=5:8).

T83 CYBER 559 Introduction to Cybersecurity
This course is intended as a comprehensive introduction to the cybersecurity field. It covers a broad range of cybersecurity terms, definitions, historical perspectives, concepts, processes, technologies, and trends, with a focus on managing risk and the employment of cybersecurity as an organizational enabler.
Credit 3 units.

T83 CYBER 560 Cybersecurity Technical Fundamentals
This course presents a comprehensive survey of cybersecurity technology, including basic theory and concepts. Students will gain hands-on familiarity with cybersecurity technology through lab exercises, in-class studios, and scenarios. Topics covered include security considerations surrounding operating systems, the web, email, databases, wireless technology, the cloud, and the Internet of Things. Also addressed are cryptography, secure software design, physical security, and human factors in cybersecurity.
Credit 3 units.

T83 CYBER 561 Oversight for Excellence: Cybersecurity Management and Governance
This course takes a comprehensive approach to the management of the organizational cybersecurity function. It also explores the principles of information technology governance. Course work provides a deeper understanding of best practices for managing cybersecurity processes and meeting multiple needs of enterprise management by balancing business risks and operational and technical imperatives. Toward this end, the course addresses a range of topics necessary for success, including the elements of and how to establish a governance program, cybersecurity management frameworks, developing and implementing a cybersecurity strategy, deploying cybersecurity policy and controls, ensuring standards and regulatory compliance, functional and budgetary advocacy, interfacing with the C-suite and board, and talent acquisition and development.
Credit 3 units.

T83 CYBER 562 Efficient and Effective Cybersecurity Operations
In this course, students will gain understanding of what it takes to manage the people, process, and technology for effective and efficient day-to-day cybersecurity operations. Using the Cybersecurity Operations Center (CSOC) as the fundamental exemplar, students will learn the functions and processes that comprise a typical CSOC with an underlying focus on continually optimizing operations and processes to ensure agility and performance. Students will examine options for structuring the CSOC and core CSOC functions and processes such as threat intelligence; monitoring, detection, and threat assessment; vulnerability management; incident response; prevention, including awareness training; partner and third-party coordination; analytics, metrics, and reporting; training; and CSOC technologies and instrumentation.
Credit 3 units.

T83 CYBER 563 Enterprise Network Security
This course presents a detailed and comprehensive study of the architecture and defensive approaches to protect enterprise network environments against cyber threats. Students will gain practical experience in secure network architectures and design approaches. Using a building-block approach along with case studies and design exercises, the course will establish the value of applied foundational security frameworks and system models. Specific topics include defensive network design, advanced treatment of appropriate security implementation tools and techniques, boundary defense, secure wireless and mobility solutions, remote and business partner access, and third-party and vendor interactions to ensure appropriate enterprise network solutions are implemented.
Credit 3 units.

T83 CYBER 564 Access Control and Identity Management
Business advancements due to technologies such as cloud, mobility, and the need to access information from anywhere using any device have made identity management and access control a critical component of cybersecurity. In this course, students will gain understanding of organizational and technical identity management and access control frameworks. They will also learn central concepts such as least privileged access, authentication, and authorization, which protect applications and systems from unapproved access. Topics covered include single sign-on, privileged account management, provisioning, role management, and directory services. Students will complete a "real-world" identity management and access control business case to identify risks and controls, and they will also create a strategy and roadmap to address challenges and propose solutions.
Credit 3 units.

T83 CYBER 565 Cybersecurity Analytics
This course provides an introduction to use of data analytics in support of an organization's cybersecurity function. The course is designed to increase student understanding of how data analytics can be used to manage security and how data analytics can be deployed in support of risk-based assessment and decision making. Students who complete this course successfully will be able to apply data analytics techniques and tools to help organizations discover anomalies pertaining to cyber threats; to implement, assess and monitor basic security functions; to respond to emerging threats or prioritized requests as defined by organizational stakeholders; to depict cybersecurity risk posture within the context of compliance and regulatory requirements; and to construct a comprehensive cybersecurity analytics framework.
Credit 3 units.

T83 CYBER 566 Cybersecurity Risk Management
In this course, students will gain deeper appreciation of the challenges faced by enterprises when addressing cybersecurity risks. The course will cover the evolution of cyber threats, including attacker methods and their targets across different industries. Students will be able to understand the differences between enterprise, operational and cybersecurity risk management and the role that each play (or should play) in managing risks to an organization. Students will gain technical understanding of industry-leading frameworks (COSO, ISO, NIST, FAIR) and become conversant with their strengths and weaknesses as well as the applicability and practicality of their implementation.
Credit 3 units.

T83 CYBER 567 The Hacker Mindset: Cyber Attack Fundamentals
This course is designed to provide an introductory understanding of how offensive security techniques practically operate. During this course, students will use hacking techniques to compromise systems, collect data, and perform other tasks that fall under the generally understood use of the term "hacker." These techniques will be related to risk-based defensive security practices, with a view toward enhancing the student's understanding of what it takes to be a successful "defender." By the conclusion of the course, students will have a baseline technical understanding of hacking techniques; they will have executed offensive security operations and increased their technical understanding of what it takes to deal with cyber threats.
Credit 3 units.

T83 CYBER 568 Emerging Issues and Technology in Cybersecurity
Each new technology advancement brings with it promises and challenges. Will it be used for good or lead to disaster? This course examines contemporary and near-future cybersecurity threats and the potential security impact of new technologies. Topics include new

forms of computing and communications and their implications for cybersecurity practitioners as well as incipient threat vectors. Historical security incidents will also be used to provide context and insight into the relationship of technology and security. Throughout the course, students will be challenged to develop strategies and responses to deal with emerging technologies and threats in the ever-evolving cybersecurity domain.
Credit 3 units.

T83 CYBER 569 Incident Response and Business Continuity
This course focuses on the end-to-end process and methods to deal with cybersecurity incidents. Using recent examples of cyber breaches and incidents, students explore how CISOs react and respond to these incidents and learn best practices for doing so. Topics include developing an incident response plan, organizing an incident response team, leveraging cyber intelligence and external partners to aid in response, handling public and private communications about the incident, and post-breach restoration. Particular attention will be paid to establishing a strong understanding of cybersecurity indicators and motives for espionage activities from both an external and rogue insider's perspective. Students will learn about host-based and network incident response tools and digital forensic tools, including techniques and tactics for their effective use. This section of the course includes key "hands-on" activities that are typically used in post-breach analysis and investigations, such as the forensic analysis of network storage, hard drives, and memory. Students will also become familiar with post-breach report construction and examine the proper drafting and use of such reports for submission to legal counsel, the courts, and organizational leaders.
Credit 3 units.

T83 CYBER 570 Managerial and Technical Approaches to Cybersecurity Assurance
How do you know if your organization is secure? How do you communicate your security posture to those who don't have expertise in cybersecurity? Many organizations fall woefully short in answering these questions. Too often gut feel takes the place of data-driven evidence of security. As a cybersecurity professional you are responsible to ensure your organization is secure and that you communicate your security posture with confidence to non-practitioners, especially your senior leadership and the board. This course provides you the concepts, methods, tools, and intellectual framework to achieve cybersecurity assurance and how you as cybersecurity leaders communicate that assurance to the C-suite and the board. Topics covered include adopting a cybersecurity maturity model, metrics selection and development, the critical role of internal and external security assessments and compliance audits, vulnerability management as a foundation of cybersecurity assurance, and how to effectively employ red/blue team activities.
Credit 3 units.

T83 CYBER 587 Cloud Security
TToday's organizations are more and more focused on delivering faster results and better products and services and doing this securely in an ever-evolving technological landscape. Cloud-based technologies have enabled the critical capabilities, functionality and innovations necessary to transform the way organizations survive and thrive in this competitive environment. As such, "the cloud" requires cybersecurity practitioners to think differently about managing risk, producing resilient solutions, and dealing with third-party providers. In this course, students will learn best practices for cloud security to include methods for architecting and applying security-related features in a cloud platform. Through case studies, standards, best practices, and studio exercises, students will develop the necessary skills to identify the security challenges of a cloud environment in support of the ongoing operations of the enterprise.
Credit 3 units.

T81 INFO 570 Leadership Seminar for Technology Professionals
This seminar is designed to develop the leadership capacity of professionals working in the information technology (IT) and cybersecurity fields. Although domain expertise plays an important role in the success of a technology professional, it is when this expertise is integrated with the ability to lead people that transforms the merely competent into multidimensional force multipliers for the organization. In this course, students will participate in an immersive seminar-based learning experience targeted toward professional and personal development on a range of essential leadership skills. Students will benefit from interaction with industry experts in the IT and cybersecurity fields and receive coaching support to achieve professional and personal goals. Each student will complete a series of self-assessments and multi-rater assessments as well as a personal leadership development plan to gain insight and build competencies critical to effective leadership. Topics include creating a shared vision, strategy development, building and sustaining a healthy culture, essentials of finance and budgeting, driving results, energizing people for performance, innovation, emotional intelligence, navigating organizational politics, managing up, negotiations, stress resilience, talent coaching and development, effective communication, and time management.
Credit 3 units.

Master of Engineering Management

The competitive Master of Engineering Management program bridges the gap between technology and business by providing students with the technical expertise and leadership skills needed to advance their careers. The 30-unit Master of Engineering Management is available for full-time or part-time students.

This program brings together Washington University faculty and industry-leading experts to help students learn to strategize, lead, make informed decisions, manage financials, and leverage both existing and emerging technology. The courses prepare individuals to utilize common management tactics across all of the engineering disciplines.

Full-time Master's Degree: 30 units, 1-1.5 years to complete

Part-time Master's Degree: 30 units, 2.5 years+ to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/engineering/index.html

Faculty

Program Director

John Bade
Director of Graduate Studies, Engineering Management
PhD, Missouri University of Science & Technology
MBA, Saint Louis University
ME, Missouri University of Science & Technology

For a list of our program faculty (https://sever.wustl.edu/faculty/#engineering_management), please visit our website.

Requirements

Master of Engineering Management

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
Required: 18 units		
ETEM 504	Engineering Management & Financial Intelligence	3
ETEM 506	Technology Strategy & Marketing	3
ETEM 510	Understanding Emerging & Disruptive Technologies	3
ETEM 530	Project Planning Methodologies	3
ETEM 582	Human Performance in the Organization	3
or ETEM 581	Leading in a Technology-Rich World	
ETEM 585	MEM Capstone	3
Electives: Choose 12 units		
Applied Data Analytics Emphasis		
INFO 506	Fundamentals of Information Technology	3
INFO 574	Foundations of Analytics	3
INFO 575	Enterprise Data Management	3
INFO 576	Analytics Applications	3
Computer Science & Security Emphasis		
CSE 501N	Introduction to Computer Science	3
CSE 502N	Data Structures and Algorithms	3
CYBER 559	Introduction to Cybersecurity	3
CYBER 560	Cybersecurity Technical Fundamentals	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3
CYBER 568	Emerging Issues and Technology in Cybersecurity	3
ETEM 505	Decision Analysis & Optimization	3
Managing, Leading & Innovating Emphasis		
ETEM 520	Intro to Innovation & Entrepreneurship	3
ETEM 525	Innovating For Defense	3
ETEM 581	Leading in a Technology-Rich World	3
ETEM 582	Human Performance in the Organization	3
ETEM 586	Cross-Cultural Negotiation	3
ETEM 587	Communication Excellence for Influential Leadership	3
MGT 501C	CEL Entrepreneurial Consulting Team	3
Project Management & Operational Excellence Emphasis		
CNST 523A	Construction Cost Estimating	3
CNST 572	Legal Aspects of Construction	3
CNST 573	Fundamentals in Construction Management	3
HLTHCARE 502	Facilitation Skills/Change Management	3
HLTHCARE 503	Lean Healthcare Concepts, Tools and Lean Management Systems	3
HLTHCARE 504	Six Sigma Concepts and Tools	3
ETEM 531	Intro to Agile Project Management	3
ETEM 532	The Art & Science of Risk Management	3

Courses

Visit online course listings to view semester offerings for T55 ETEM (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T55&crslvl=5:8).

T55 ETEM 504 Engineering Management & Financial Intelligence
Discover the full picture of how business works within the organization. This course walks the student through the complete business cycle -- the roles the various functions play in a business operation as well as how information is used to make business decisions (e.g. financial data, marketing data, production data, economic data). To bring these learnings to life, this course also uses management simulation games and classroom competitions. Includes strategy, product planning and management, sales and support, research and development, manufacturing and supply chain, with particular emphasis on accounting, finance and the use of financial statements.
Credit 3 units.

T55 ETEM 505 Decision Analysis & Optimization
Expand your ability to analyze and optimize complex business situations by leveraging the key data. Decision-making in today's complex world requires advanced analytical methods and tools, including mathematical modeling and quantitative techniques. Powerful tools for forecasting, finance, operations, production and logistics. Emerging technologies such as the Industrial Internet of Things (I-IoT) and Block Chain are enabling a whole new set of possibilities!
Credit 3 units.

T55 ETEM 506 Technology Strategy & Marketing
Learn the art and science of technology-rich strategy and marketing. Every business rises and falls on the value it brings to the customer and the value it simultaneously brings to the business itself. The engineer that understands and can communicate strategy and marketing is

powerful! Business, technology and research budgets are allocated based on this value proposition, whether the commercialization or operationalization of the technology is 1 year out or 10 years out. Prerequisite: T55 504.
Credit 3 units.

T55 ETEM 510 Understanding Emerging & Disruptive Technologies
We live in an era of rapid technology innovation and disruption. Blockbuster was the darling of Wall Street in 2004 and filed for bankruptcy in 2010. Blockbuster CEO in 2008: "Neither Redbox nor Netflix are even on the radar screen in terms of competition." Blockbuster is not alone in their blindness. Microsoft laughed off the first i-phone, and laughed off Google. IBM laughed off the first personal computer. These should be a horrible warning to all business leaders. Numerous technologies are threatening disruption today: block chain, Internet of Things (IoT), artificial intelligence, autonomous vehicles, unmanned aerial vehicles (UAVs), 3D printing, 5G wireless networks, gene editing. Understanding what they are and how they might disrupt will make or break countless companies in the coming years.
Credit 3 units.

T55 ETEM 520 Intro to Innovation & Entrepreneurship
What exactly is innovation, and what is entrepreneurship? How do they drive business and society? Where do good ideas come from? Can anyone learn to be innovative or be an entrepreneur, and does "thinking like an engineer" help or hinder this process? What does an innovative organization look and act like? What barriers exist to innovation/entrepreneurship, and can they be overcome? This course introduces important frameworks and concepts, offers the student hands-on individual and team learning, includes numerous guest lecturers, and cultivates essential communication skills, all with the goal of fostering an understanding of, and confidence in, innovation and entrepreneurship - both for the individual as well as for the organization.
Credit 3 units.

T55 ETEM 525 Innovating For Defense
This interdisciplinary entrepreneurial course gives students the unique opportunity to solve real problems facing the U.S. Department of Defense (DoD) and the U.S. Intelligence Community (IC). This course is open to all students who want to solve real problems for real customers in real time. Students will form their own interdisciplinary teams. Each team chooses their own DoD problems from those available to the class. Each problem has a dedicated DoD problem sponsor who will be regularly engaged with the team. Student teams learn and use the Lean Startup methodology and the Mission Model Canvas made famous by Stanford University to iteratively cut through the complexity of the problem. Teams develop a keen understanding of the problem, craft a business model and solution, and develop a prototype. Note: This course is sponsored by the U.S. DoD. It was originally developed at Stanford University and is now taught at 30+ U.S. universities. A student does NOT have to be a citizen of the United States to take this course; none of the DoD problems are classified. Recommended completion of T55 ETEM 520.
Credit 3 units.

T55 ETEM 581 Leading in a Technology-Rich World
Leadership has fundamentally changed from top-down, autocratic and task-focused to collaborative and people-focused in just a few generations. Great senior leaders now get their people to do the greatest things. They must constantly learn, think innovatively, move and adapt very quickly, and collaborate over short and long distances. Students will learn new leadership skills, explore their individual leadership styles, and discuss the senior leadership challenges in an evolving tech-rich world.
Credit 3 units.

T55 ETEM 582 Human Performance in the Organization
Have you ever wondered why some careers soar and others stall? Why you find it easy to build relationships with some people - but not others? Why some teams function well and consistently outperform others? Are you curious about what kind of manager you are, or will be? Do you want to know more about how organizations decide who to hire and who to promote? Human Performance in the Organization is designed to help you answer these questions. The content is a mix of relevant theory, personal reflection, and practical application. Our goal is to understand human performance at all levels of the organization. Topics include performance and career management; negotiation and influence; power and politics; mentoring and coaching; high-performance teams; conflict management; talent development and succession planning; and change management.
Credit 3 units.

T55 ETEM 585 MEM Capstone
The MEM capstone course is the culmination of the Master of Engineering Management degree program. Taken at the end of the program, the capstone course gives each student (as part of a team) an opportunity to apply a cross-section of knowledge and skills gained toward a current challenge/project from industry, government or nonprofit organization. Student teams are encouraged to interface with the sponsoring organization throughout the semester. Prerequisite: Completion or co-enrollment in all Required MEM courses.
Credit 3 units.

T55 ETEM 586 Cross-Cultural Negotiation
This course introduces students to and gives them practice with principle-based tools and techniques to reach agreements across varied cultures. Best practices from the most famous negotiators of ancient history (i.e., the Phoenicians) are studied and used as a methodology that includes the role of a third party in resolving conflict. The cross-cultural elements are based on multicultural experiences, research studies and the real-life experiences of the instructor. The course is highly interactive (about 70% of the course work). Participants learn through role plays and simulation as well as through readings and case-study analysis.
Credit 3 units.

T55 ETEM 587 Communication Excellence for Influential Leadership
Exceptional communicators become extraordinary leaders. This course will guide students to learn to exceptionally communicate their message by applying refined nuances that inspire and transform those with whom they converse. Through a proven communicative process, students will acquire skills necessary to differentiate them as leaders. Students will learn how to communicate across a variety of settings using strategies that result in clear, vivid, and engaging exchanges. Students will practice: storytelling; creating and using clear visuals; engaging listeners; demonstrating passion when speaking; responding to questions with clarity and brevity, and, using their distinctive voice as a leadership asset. Each student will learn how to assess his or her own communication capabilities, adjust to different listeners, and how to evaluate speaker effectiveness and provide valuable feedback to others. Video recordings will be used to demonstrate incremental communicative changes throughout the course, and to show how these strategies bring about outstanding leadership.
Credit 3 units.

Master of Information Systems Management

Building on more than 30 years of innovative graduate education and professional development programs in information technology, the McKelvey School of Engineering at Washington University in St. Louis now offers a 30-unit Master of Information Systems Management. This program combines the best of two very successful programs that have attracted students from across the world: the Master of Information Systems and the Master of Information Management. This integrated program is a key component of Washington University's strategy to prepare the next generation of technology leaders. The 30-unit Master of Information Systems Management brings together candidates with interests and backgrounds in technology and management into a blend of outstanding courses led by Washington University faculty and industry leaders in information, systems, management and leadership.

Full-time Master's Degree: 30 units, 1-1.5 years to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/information-systems/index.html

Faculty

Program Director

Saeed Akbani
Director of Graduate Studies, Information Systems Management
MBA, Washington University in St. Louis
MS, Electrical Engineering, University of Michigan
BS, Electrical & Electronics Engineering, Washington University in St. Louis

For a list of our program faculty (https://sever.wustl.edu/degree-programs/information-systems/), please visit our website.

Requirements

Master of Information Systems Management

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
Required: 18 units		
CYBER 559	Introduction to Cybersecurity	3
INFO 517	Operational Excellence & Service Delivery	3
INFO 540	IT Architecture & Infrastructure	3
INFO 563	IT Governance & Risk Management	3
INFO 575	Enterprise Data Management	3
INFO 585	Capstone	3
Electives: Choose 12 units		
Cybersecurity Emphasis		
CYBER 560	Cybersecurity Technical Fundamentals	3
CYBER 561	Oversight for Excellence: Cybersecurity Management and Governance	3
CYBER 562	Efficient and Effective Cybersecurity Operations	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3
CYBER 568	Emerging Issues and Technology in Cybersecurity	3
Management Emphasis		
ETEM 504	Engineering Management & Financial Intelligence	3
ETEM 505	Decision Analysis & Optimization	3
ETEM 582	Human Performance in the Organization	3
ETEM 587	Communication Excellence for Influential Leadership	3
Applied Data Analytics & Machine Learning Emphasis		
INFO 552	Special Topics in Information Technology	3
INFO 558	Applications of Deep Neural Networks	3
INFO 574	Foundations of Analytics	3
INFO 576	Analytics Applications	3
Mathematical Data Analytics Emphasis		
CSE 412A	Introduction to Artificial Intelligence	3
CSE 417T	Introduction to Machine Learning	3
CSE 514A	Data Mining	3
CSE 517A	Machine Learning	3
ESE 415	Optimization	3
Math 494	Mathematical Statistics	3
AI & Machine Learning Emphasis		
CSE 412A	Introduction to Artificial Intelligence	3
CSE 417T	Introduction to Machine Learning	3
CSE 514A	Data Mining	3
CSE 517A	Machine Learning	3
CSE 519T	Advanced Machine Learning	3
Bridge Course*		
INFO 506	Fundamentals of Information Technology	3

* The bridge course is offered for students with limited to no information systems background. The successfully completed course will count toward the 12 required elective units.

Courses

Visit online course listings to view semester offerings for T81 INFO (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T81&crslvl=5:8).

T81 INFO 506 Fundamentals of Information Technology
This course is designed to provide a comprehensive survey of the information technology field. The enterprise relies heavily on information technology to generate value, efficiency, and effectiveness. As such, organizational leaders must ensure that the enterprise transforms to keep pace in the competitive environment. Globalization, mergers and acquisitions, and the proliferation of new business and operating models require management to continuously reconsider technology infrastructures, organizational structures, process re-engineering, outsourcing, innovation, technology effectiveness, and the creation and management of data and knowledge. Given these challenges and opportunities, the IT professional has never been more crucial to organizational success. In this context, students will become familiar with core IT concepts, processes, and technology and gain an increased understanding of the crucial role of IT in the modern enterprise.
Credit 3 units.

T81 INFO 517 Operational Excellence & Service Delivery
This course examines needed management skills and processes for the efficient and effective functioning of IT infrastructure and operational environments to deliver the right set of services at the right quality and at the right costs for internal and external users and customers. Specific emphasis is placed on understanding the roles of IT operations, including system administration, network administration, help desk services, asset management, DevOps, and reporting. Students will study the application of industry best practice frameworks for the management of IT infrastructure, operations, and development. Frameworks covered include the Information Technology Infrastructure Library (ITIL) and Control Objectives for Information and Related Technology (COBIT). Through the application of continuous service improvement, students will understand the IT service life cycle and be able to assess the effectiveness of processes and services.
Credit 3 units.

T81 INFO 540 IT Architecture & Infrastructure
This course will demonstrate the importance of understanding organizational strategies and goals and then designing and deploying an information technology (IT) infrastructure that supports those strategies and goals. The course will showcase how fundamental IT building blocks are integrated in meaningful ways in order to support IT services that drive core business outcomes. Through a hands-on enterprise architecture design project, students will learn to design IT infrastructure in a rational, innovative, and cost-effective manner. We will cover a range of enterprise architecture design considerations that are commonly faced by organizations as they enhance their services, launch new products, or expand to new markets.
Credit 3 units.

T81 INFO 552 Special Topics in Information Technology
The material for this course varies among offerings, but this course generally covers advanced or specialized topics in emerging topics in information technology, data science, and cybersecurity.
Credit 3 units.

T81 INFO 558 Applications of Deep Neural Networks
Deep learning is a group of exciting new technologies for neural networks. It is now possible to create neural networks of much greater complexity through a combination of advanced training techniques and neural network architectural components. Deep learning allows a neural network to learn hierarchies of information in a way that is like the function of the human brain. This course will introduce the student to computer vision with Convolution Neural Networks (CNN), time series analysis with Long Short-Term Memory (LSTM), transformers, large language models (LLMs), and classic neural network structures. The focus is primarily on applying deep learning to problems, with some introduction to mathematical foundations. High-Performance Computing (HPC) aspects demonstrate how you can leverage deep learning on graphical processing units (GPUs). Students will use Python to implement deep learning using PyTorch and other libraries. It is unnecessary to know Python before this course; however, familiarity with at least one programming language is assumed. We deliver this course in a hybrid format, including classroom and online instruction.
Credit 3 units.

T81 INFO 563 IT Governance & Risk Management
Firms with superior IT governance designed to support the organization's strategy achieve better performance and higher profits than firms with poor (or no) governance. Just as corporate governance aims to ensure quality decisions about all corporate assets, IT governance links IT decisions with company objectives and monitors performance and accountability. We will start with developing an understanding of IT governance and go over the decision-rights and decision-making processes associated with it. We will study various enterprise operating models and strategies and see how they in turn determine the IT strategy and operating model. We will also review practices to provide business oversight and transparency into IT investments and go over how IT leaders can proactively partner with other business leaders to drive top-line growth and/or operational cost savings. We will also review how to classify initiatives into projects and programs and group them into portfolios. Furthermore, we will discuss different project implementation approaches, ranging from waterfall to agile methodologies. We will also cover how many IT departments are transitioning towards a more productized delivery model. Finally, we will also review technology selection processes, architectural governance, procurement of products and services, as well as service and vendor management. Throughout this process, we will be reviewing decision-making from the perspective of both leveraging business opportunities and managing risk. Risk management is an essential component of an IT leader's role. We will cover the risk management process and use it to identify and manage & control some of the common risks that contemporary IT organizations face. This includes guarding against cyber threats, protecting data, and managing vendor, business continuity, regulatory, project, and operational risks etc.
Credit 3 units.

T81 INFO 574 Foundations of Analytics
The steeply decreasing costs of gathering, storing, and processing data have created a strong motivation for organizations to move toward "data-driven" approaches to problem solving. As such, data analytics continues to grow rapidly in importance across industry, government, and nonprofit organizations. This course seeks to equip students with a wide range of data analytics techniques that serve as the foundation for a broad range of applications, including descriptive, inferential, predictive, and prescriptive analytics. Students will learn the process of building a data model as well as a variety of analytics techniques and under what situations they are best employed. Through lectures and practical exercises, students will become familiar with the computational mathematics that underpin analytics; the elements of statistical modeling and machine learning; model interpretation and assessment; and structured and unstructured data analysis. Students will also undertake a project to build an analytical model using a "real-world" data set.
Credit 3 units.

T81 INFO 575 Enterprise Data Management
In the 4th Industrial Revolution of Digital Transformation, Data is a key and necessary foundational element. Enterprise Data Management is the responsibility and opportunity to effectively utilize data and make it useful to achieve organizational goals. Organizations have begun generating, collecting, and accumulating more data at a faster pace than ever before. The advent of "Big Data" has proven to be both an

opportunity and challenge for organizations who are awash, even drowning-in data, but starved for knowledge. Unfortunately, many organizations have not developed comprehensive enterprise data management (EDM) practices that treat data as a true organizational asset. EDM is a comprehensive approach to defining, governing, securing, and maintaining the access and quality of the right data involved in the business processes of an organization. This course will cover many aspects of building an enterprise data management program, including areas such as data governance, data security, data architecture, data quality, data ownership, metadata management, data strategy, and others.
Credit 3 units.

T81 INFO 576 Analytics Applications
This course builds on the content taught in Enterprise Data Management and Foundations of Data Analytics. It focuses on the strategic, operational, tactical, and practical use of data analytics to inform decisions within an organization across a range of industry and government sectors as well as within organizational functions. Students will be introduced to specific analytics techniques that are used currently by practitioners in areas of diagnostic, descriptive, predictive, and prescriptive analytics. Students will learn the critical phases of analytics including data preparation, model development, evaluation, validation, selection, and deployment. In so doing, students will learn to apply data analytics in order to optimize organizational processes, improve performance, and inform decision-making. Recommended completion of T81 574.
Credit 3 units.

T81 INFO 585 Capstone
This capstone course is the culmination of the Masters of Information Systems Management program. The capstone project provides the opportunity for students to employ the knowledge and skills they have gained from their course work in a rigorous and systematic manner. Projects are sponsored by external corporate, government, and non-profit organizations, and they provide the opportunity for students to deliver meaningful research and recommendations for "real-world" IT challenges and problems.
Credit 3 units.

Online Degree Programs

Online Master of Cybersecurity Management

This exclusively online, part-time program was developed for cybersecurity working professionals seeking to advance their leadership skills and to deepen the managerial acumen required to establish, maintain, and develop an effective and efficient cybersecurity enterprise. Students in this 30-unit program will acquire the expertise needed to successfully execute a range of core cybersecurity functions, including governance, operations, incident response, and architecting technical solutions. The program places particular emphasis on business-related skills such as communicating with non-technical line-of-business leaders and peers, speaking the language of business, and strategy formulation and development. Graduates of this program will be well prepared to step into positions of greater responsibility and to make larger and more consequential contributions to their organizations.

Part-time Master's Degree: 30 units, 2.5 years+ to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/cybersecurity/index.html

Faculty

Program Director

Joe Scherrer (https://sever.wustl.edu/faculty/Pages/Joe-Scherrer.aspx)
Executive Director, Professional Education
Director, Cybersecurity Strategic Initiative
Program Director, Graduate Studies in Cybersecurity Management
Doctor of Liberal Arts, Washington University in St. Louis, 2023 (projected)
MS, Business Administration, Boston University
MS, Information Systems Management, Air Force Institute of Technology
MS, National Security Studies, Naval War College
MS, Strategic Studies, Air War College
BS, Electrical Engineering, Washington University in St. Louis

For a list of our program faculty (https://sever.wustl.edu/faculty/#cybersecurity_management), please visit our website.

Requirements

Online Master of Cybersecurity Management

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Course numbers below are subject to change. Please contact the Sever Institute Assistant Director of Academic & Student Services for accurate academic advising information.

Code	Title	Units
Required: 21 units		
CSM 660	Cybersecurity Technical Fundamentals	3
CSM 661	Oversight for Excellence: Cybersecurity Management and Governance	3
CSM 662	Efficient and Effective Cybersecurity Operations	3
CSM 666	Cybersecurity Risk Management	3
CSM 667	The Hacker Mindset: Cyber Attack Fundamentals	3
CSM 687	Cloud Security	3

INFO 570	Leadership Seminar for Technology Professionals	3
Electives: Choose 9 units		
CSM 663	Enterprise Network Security	3
CSM 664	Access Control and Identity Management	3
CSM 665	Cybersecurity Analytics	3
CSM 668	Emerging Issues and Technology in Cybersecurity	3
CSM 669	Incident Response and Business Continuity	3
CSM 670	Managerial and Technical Approaches to Cybersecurity Assurance	3
Bridge Course*		
CSM 659	Introduction to Cybersecurity	3

* The bridge course is offered for students with limited to no cybersecurity background. The successfully completed course will count toward the 9 required elective units.

Courses

Visit online course listings to view semester offerings for T93 CSM (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T93&crslvl=5:8).

T93 CSM 659 Introduction to Cybersecurity
This course is intended as a comprehensive introduction to the cybersecurity field. It covers a broad range of cybersecurity terms, definitions, historical perspectives, concepts, processes, technologies, and trends, with a focus on managing risk and the employment of cybersecurity as an organizational enabler.
Credit 3 units.

T93 CSM 660 Cybersecurity Technical Fundamentals
This course presents a comprehensive survey of cybersecurity technology, including basic theory and concepts. Students will gain hands-on familiarity with cybersecurity technology through lab exercises, in-class studios, and scenarios. Topics covered include security considerations surrounding operating systems, the web, email, databases, wireless technology, the cloud, and the Internet of Things. Also addressed are cryptography, secure software design, physical security, and human factors in cybersecurity.
Credit 3 units.

T93 CSM 661 Oversight for Excellence: Cybersecurity Management and Governance
This course takes a comprehensive approach to the management of the organizational cybersecurity function. It also explores the principles of information technology governance. Course work provides a deeper understanding of best practices for managing cybersecurity processes and meeting multiple needs of enterprise management by balancing business risks and operational and technical imperatives. Toward this end, the course addresses a range of topics necessary for success, including the elements of and how to establish a governance program, cybersecurity management frameworks, developing and implementing a cybersecurity strategy, deploying cybersecurity policy and controls, ensuring standards and regulatory compliance, functional and budgetary advocacy, interfacing with the C-suite and board, and talent acquisition and development.
Credit 3 units.

T93 CSM 662 Efficient and Effective Cybersecurity Operations
In this course, students will gain understanding of what it takes to manage the people, process, and technology for effective and efficient day-to-day cybersecurity operations. Using the Cybersecurity Operations Center (CSOC) as the fundamental exemplar, students will learn the functions and processes that comprise a typical CSOC with an underlying focus on continually optimizing operations and processes to ensure agility and performance. Students will examine options for structuring the CSOC and core CSOC functions and processes such as threat intelligence; monitoring, detection, and threat assessment; vulnerability management; incident response; prevention, including awareness training; partner and third-party coordination; analytics, metrics, and reporting; training; and CSOC technologies and instrumentation.
Credit 3 units.

T93 CSM 663 Enterprise Network Security
TThis course presents a detailed and comprehensive study of the architecture and defensive approaches to protect enterprise network environments against cyber threats. Students will gain practical experience in secure network architectures and design approaches. Using a building-block approach along with case studies and design exercises, the course will establish the value of applied foundational security frameworks and system models. Specific topics include defensive network design, advanced treatment of appropriate security implementation tools and techniques, boundary defense, secure wireless and mobility solutions, remote and business partner access, and third-party and vendor interactions to ensure appropriate enterprise network solutions are implemented.
Credit 3 units.

T93 CSM 664 Access Control and Identity Management
Business advancements due to technologies such as cloud, mobility, and the need to access information from anywhere using any device have made identity management and access control a critical component of cybersecurity. In this course, students will gain understanding of organizational and technical identity management and access control frameworks. They will also learn central concepts such as least privileged access, authentication, and authorization, which protect applications and systems from unapproved access. Topics covered include single sign-on, privileged account management, provisioning, role management, and directory services. Students will complete a "real-world" identity management and access control business case to identify risks and controls, and they will also create a strategy and roadmap to address challenges and propose solutions.
Credit 3 units.

T93 CSM 665 Cybersecurity Analytics
This course provides an introduction to use of data analytics in support of an organization's cybersecurity function. The course is designed to increase student understanding of how data analytics can be used to manage security and how data analytics can be deployed in support of risk-based assessment and decision making. Students who complete this course successfully will be able to apply data analytics techniques and tools to help organizations discover anomalies pertaining to cyber threats; to implement, assess and monitor basic security functions; to respond to emerging threats or prioritized requests as defined by organizational stakeholders; to depict cybersecurity risk posture within the context of compliance and regulatory requirements; and to construct a comprehensive cybersecurity analytics framework.
Credit 3 units.

T93 CSM 666 Cybersecurity Risk Management
In this course, students will gain deeper appreciation of the challenges faced by enterprises when addressing cybersecurity risks. The course will cover the evolution of cyber threats, including attacker methods and their targets across different industries. Students will be able to understand the differences between enterprise, operational and cybersecurity risk management and the role that each play (or should play) in managing risks to an organization. Students will gain technical understanding of industry-leading frameworks (COSO, ISO, NIST, FAIR) and become conversant with their strengths and weaknesses as well as the applicability and practicality of their implementation.
Credit 3 units.

T93 CSM 667 The Hacker Mindset: Cyber Attack Fundamentals
This course is designed to provide an introductory understanding of how offensive security techniques practically operate. During this course, students will use hacking techniques to compromise systems, collect data, and perform other tasks that fall under the generally understood use of the term "hacker." These techniques will be related to risk-based defensive security practices, with a view toward enhancing the student's understanding of what it takes to be a successful "defender." By the conclusion of the course, students will have a baseline technical understanding of hacking techniques; they will have executed offensive security operations and increased their technical understanding of what it takes to deal with cyber threats.
Credit 3 units.

T93 CSM 668 Emerging Issues and Technology in Cybersecurity
Each new technology advancement brings with it promises and challenges. Will it be used for good or lead to disaster? This course examines contemporary and near-future cybersecurity threats and the potential security impact of new technologies. Topics include new forms of computing and communications and their implications for cybersecurity practitioners as well as incipient threat vectors. Historical security incidents will also be used to provide context and insight into the relationship of technology and security. Throughout the course, students will be challenged to develop strategies and responses to deal with emerging technologies and threats in the ever-evolving cybersecurity domain.
Credit 3 units.

T93 CSM 669 Incident Response and Business Continuity
This course focuses on the end-to-end process and methods to deal with cybersecurity incidents. Using recent examples of cyber breaches and incidents, students explore how CISOs react and respond to these incidents and learn best practices for doing so. Topics include developing an incident response plan, organizing an incident response team, leveraging cyber intelligence and external partners to aid in response, handling public and private communications about the incident, and post-breach restoration. Particular attention will be paid to establishing a strong understanding of cybersecurity indicators and motives for espionage activities from both an external and rogue insider's perspective. Students will learn about host-based and network incident response tools and digital forensic tools, including techniques and tactics for their effective use. This section of the course includes key "hands-on" activities that are typically used in post-breach analysis and investigations, such as the forensic analysis of network storage, hard drives, and memory. Students will also become familiar with post-breach report construction and examine the proper drafting and use of such reports for submission to legal counsel, the courts, and organizational leaders.
Credit 3 units.

T93 CSM 670 Managerial and Technical Approaches to Cybersecurity Assurance
Today's organizations are more and more focused on delivering faster results and better products and services and doing this securely in an ever-evolving technological landscape. Cloud-based technologies have enabled the critical capabilities, functionality and innovations necessary to transform the way organizations survive and thrive in this competitive environment. As such, "the cloud" requires cybersecurity practitioners to think differently about managing risk, producing resilient solutions, and dealing with third-party providers. In this course, students will learn best practices for cloud security to include methods for architecting and applying security-related features in a cloud platform. Through case studies, standards, best practices, and studio exercises, students will develop the necessary skills to identify the security challenges of a cloud environment in support of the ongoing operations of the enterprise.
Credit 3 units.

T93 CSM 687 Cloud Security
Today's organizations are more and more focused on delivering faster results and better products and services and on doing this securely via an ever-evolving technological landscape. As a key component of the competitive landscape, cloud-based technologies have enabled the critical capabilities, functionality and innovations necessary to transform the way organizations survive and thrive in the competitive environment. As such, "the cloud" requires cybersecurity practitioners to think differently about managing risk, producing resilient solutions, and dealing with third-party providers. In this course, students will learn best practices for cloud security to include methods for architecting and applying security-related features in a cloud platform. Through case studies, standards, best practices, and studio exercises, students will develop the necessary skills to identify the security challenges of a cloud environment in support of the ongoing operations of the enterprise.
Credit 3 units.

Online Master of Engineering Management

The competitive, part-time Online Master of Engineering Management program bridges the gap between technology and business by providing students with the technical expertise and leadership skills needed to advance their careers.

This program brings together Washington University faculty and industry-leading experts to help students learn to strategize, lead, make informed decisions, manage financials, and leverage both existing and emerging technology. The courses prepare individuals to utilize common management tactics across all of the engineering disciplines.

Part-time Master's Degree: 30 units, 2.5 years+ to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/engineering/index.html

Faculty

Program Director

John Bade
Director of Graduate Studies, Engineering Management
PhD, Missouri University of Science & Technology
MBA, Saint Louis University
ME, Missouri University of Science & Technology

For a list of our program faculty (https://sever.wustl.edu/faculty/#engineering_management), please visit our website.

Requirements

Master of Engineering Management

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
EMGT 604	Engineering Management & Financial Intelligence	3
EMGT 606	Technology Strategy & Marketing	3
EMGT 610	Understanding Emerging & Disruptive Technologies	3
EMGT 620	Intro to Innovation & Entrepreneurship	3
EMGT 630	Project Planning Methodologies	3
EMGT 625 Innovating for Defense **or** EMGT 632 The Art & Science of Risk Management		3
EMGT 681 Leading in a Technology-Rich World **or** EMGT 682 Human Performance in the Organization		3
EMGT 686	Cross-Cultural Negotiations	3
EMGT 687	Communication Excellence for Influential Leadership	3
EMGT 685	MEM Capstone	3
Total Units		**30**

Courses

Visit online course listings to view semester offerings for T95 EMGT (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T95&crslvl=5:8).

T95 EMGT 604 Engineering Management & Financial Intelligence
Discover the full picture of how business works within the organization. This course walks the student through the complete business cycle -- the roles the various functions play in a business operation as well as how information is used to make business decisions (e.g. financial data, marketing data, production data, economic data). To bring these learnings to life, this course also uses management simulation games and classroom competitions. Includes strategy, product planning and management, sales and support, research and development, manufacturing and supply chain, with particular emphasis on accounting, finance and the use of financial statements.
Credit 3 units.

T95 EMGT 606 Technology Strategy & Marketing
Learn the art and science of technology-rich strategy and marketing. Every business rises and falls on the value it brings to the customer and the value it simultaneously brings to the business itself. The engineer that understands and can communicate strategy and marketing is powerful! Business, technology and research budgets are allocated based on this value proposition, whether the commercialization or operationalization of the technology is 1 year out or 10 years out.
Prerequisite: T55 ETEM 504.
Credit 3 units.

T95 EMGT 610 Understanding Emerging & Disruptive Technologies
We live in an era of rapid technology innovation and disruption. Blockbuster was the darling of Wall Street in 2004 and filed for bankruptcy in 2010. Blockbuster CEO in 2008: "Neither Redbox nor Netflix are even on the radar screen in terms of competition." Blockbuster is not alone in their blindness. Microsoft laughed off the first iPhone, and laughed off Google. IBM laughed off the first personal computer. These should be a horrible warning to all business leaders. Numerous technologies are threatening disruption today: block chain, Internet of Things (IoT), artificial intelligence, autonomous vehicles, unmanned aerial vehicles (UAVs), 3D Printing, 5G wireless networks, gene editing. Understanding what they are and how they might disrupt will make or break countless companies in the coming years.
Credit 3 units.

T95 EMGT 620 Intro to Innovation & Entrepreneurship
What exactly is innovation, and what is entrepreneurship? How do they drive business and society? Where do good ideas come from? Can anyone learn to be innovative or be an entrepreneur, and does "thinking like an engineer" help or hinder this process? What does an innovative organization look and act like? What barriers exist to innovation/entrepreneurship, and can they be overcome? This course introduces important frameworks and concepts, offers the student hands-on individual and team learning, includes numerous guest lecturers, and cultivates essential communication skills, all with the goal of fostering an understanding of, and confidence in, innovation and entrepreneurship -- both for the individual as well as for the organization.
Credit 3 units.

T95 EMGT 625 Innovating for Defense
This interdisciplinary entrepreneurial course gives students the unique opportunity to solve real problems facing the U.S. Department of Defense (DoD) and the U.S. Intelligence Community (IC). This course is open to all students who want to solve real problems for real customers in real time. Students will form their own interdisciplinary teams. Each team chooses their own DoD problems from those available to the class. Each problem has a dedicated DoD problem sponsor who will be regularly engaged with the team. Student teams learn and use the Lean Startup methodology and the Mission Model Canvas made famous by Stanford University to iteratively cut through the complexity of the problem. Teams develop a keen understanding of the problem, craft

a business model and solution, and develop a prototype. Note: This course is sponsored by the U.S. DoD. It was originally developed at Stanford University and is now taught at 30+ U.S. universities. A student does NOT have to be a citizen of the United States to take this course; none of the DoD problems are classified. Recommended completion of T55 ETEM 520.
Credit 3 units.

T95 EMGT 630 Project Planning Methodologies
Build your expertise with today's critical project management methodologies in our fast-paced world. Variations of waterfall are widely used in industry, but new uses of agile are being discovered every day, both inside and outside of software-based organizations. This course exposes the student to the fundamental and emerging techniques and tools used to manage successful projects of various sizes and complexity -- managing cost, schedule, quality, risk, solution and requirements -- while adapting to today's fast-paced and uncertain business environment. The primary focus of this course is on agile.
Credit 3 units.

T95 EMGT 632 The Art & Science of Risk Management
This course focuses on why many project managers miss requirements for schedule, budget or even both. The course concentrates on key risk management techniques practiced by leading project and program managers and taught through fact-filled lectures, case work and project execution as applied to information systems, engineering, financial, product/process and design projects/programs in today's fast-moving environment. Students will take away key value propositions, including risk identification, risk quantification, risk monitoring, risk control and risk mitigation. This course will enable the student to address common scope, schedule, quality and cost risk events that occur on complex projects. Project risk management examines the types of risk, with a focus on understanding the process of risk identification, assessment, prevention, mitigation, and recovery; governance, auditing, and control of confidentiality; integrity; and availability of data. Using common operational, strategic, tactical, and technological scenarios, the course work provides a comprehensive approach to the challenges faced by managers when global data is readily available, risk is pervasive, regulations are ever-increasing, and the threat of disruption from potential crises is real.
Credit 3 units.

T95 EMGT 681 Leading in a Technology-Rich World
Leadership has fundamentally changed from top-down, autocratic and task-focused to collaborative and people-focused in just a few generations. Great senior leaders now get their people to do the greatest things. They must constantly learn, think innovatively, move and adapt very quickly, and collaborate over short and long distances. Students will learn new leadership skills, explore their individual leadership styles, and discuss the senior leadership challenges in an evolving tech-rich world.
Credit 3 units.

T95 EMGT 682 Human Performance in the Organization
Have you ever wondered why some careers soar and others stall? Why you find it easy to build relationships with some people - but not others? Why some teams function well and consistently outperform others? Are you curious about what kind of manager you are, or will be? Do you want to know more about how organizations decide who to hire and who to promote? Human Performance in the Organization is designed to help you answer these questions. The content is a mix of relevant theory, personal reflection, and practical application. Our goal is to understand human performance at all levels of the organization. Topics include performance and career management; negotiation and influence; power and politics; mentoring and coaching; high-performance teams; conflict management; talent development and succession planning; and change management.
Credit 3 units.

T95 EMGT 685 MEM Capstone
The MEM capstone course is the culmination of the Master of Engineering Management degree program. Taken at the end of the program, the capstone course gives each student (as part of a team) an opportunity to apply a cross-section of knowledge and skills gained toward a current challenge/project from industry, government or nonprofit organization. Student teams are encouraged to interface with the sponsoring organization throughout the semester. Prerequisite: Completion or co-enrollment in all Required MEM courses.
Credit 3 units.

T95 EMGT 686 Cross-Cultural Negotiation
This course introduces students to and gives them practice with principle-based tools and techniques to reach agreements across varied cultures. Best practices from the most famous negotiators of ancient history (i.e., the Phoenicians) are studied and used as a methodology that includes the role of a third party in resolving conflict. The cross-cultural elements are based on multicultural experiences, research studies and the real-life experiences of the instructor. The course is highly interactive (about 70% of the course work). Participants learn through role plays and simulation as well as through readings and case-study analysis.
Credit 3 units.

T95 EMGT 687 Communication Excellence for Influential Leadership
Exceptional communicators become extraordinary leaders. This course will guide students to learn to exceptionally communicate their message by applying refined nuances that inspire and transform those with whom they converse. Through a proven communicative process, students will acquire skills necessary to differentiate them as leaders. Students will learn how to communicate across a variety of settings using strategies that result in clear, vivid, and engaging exchanges. Students will practice: storytelling; creating and using clear visuals; engaging listeners; demonstrating passion when speaking; responding to questions with clarity and brevity, and, using their distinctive voice as a leadership asset. Each student will learn how to assess his or her own communication capabilities, adjust to different listeners, and how to evaluate speaker effectiveness and provide valuable feedback to others. Video recordings will be used to demonstrate incremental communicative changes throughout the course, and to show how these strategies bring about outstanding leadership.
Credit 3 units.

T95 EMGT 699 Applied Research Study
Applied Research Study (ARS) is an advanced, project-based course designed to allow students to develop in-depth knowledge and further their education building on the education offered in the Programs. Applied research is a type of examination looking to find practical solutions for existing problems. These can include challenges in the workplace, education, and society. Students collaborate with an

adjunct faculty advisor to collect data. Findings are applicable and may be implemented upon completion of a study. Applied research focuses on answering one specific applied research question for a client or sponsor. Applied Research Study must have prior approval of a faculty sponsor and the Program Director.
Credit 3 units.

Online Master of Health Care Operational Excellence

Managing health care systems today is more than process efficiencies and quality assessment. At every level and dimension, it takes an interdisciplinary approach to get it right. The Master of Health Care Operational Excellence (MHCOE) can help you advance with the knowledge, leadership and skills needed to establish, implement and oversee important process analysis and continuous improvement initiatives in the growing field of health care.

Designed with input from employers, thought leaders, and practitioners, the MHCOE program is taught by leading health care professionals, experts and executives. This program provides a solid foundation in the areas of project management fundamentals, navigating organizational change, process improvement, human-centered design, operations and finance, and emerging issues in health care and related service organizations. The program also addresses the more nuanced human factors and topics of personal leadership and resilience.

Part-time Master's Degree: 30 units, 2.5 years+ to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/healthcare/index.html

Faculty

Program Director

Leroy Love (https://sever.wustl.edu/faculty/Pages/Leroy-Love.aspx)
Director of Graduate Studies in Health Care Operational Excellence
MS, Missouri University of Science & Technology
BS, University of Missouri-Columbia

For a list of our program faculty (https://sever.wustl.edu/faculty/#health_care_operational_excellence), please visit our website.

Requirements

Master of Health Care Operational Excellence

Total units required: 30

In order to earn the degree, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the degree.

Code	Title	Units
HCO 601	Introductory Overview of Operational Excellence in Healthcare	3
HCO 602	Facilitation Skills / Change Management	3
HCO 607	Project Management in Healthcare	3
HCO 603	Lean Healthcare Concepts, Tools and Lean Management Systems	3
HCO 604	Six Sigma Concepts and Tools	3
HCO 606	Innovation Science and Human Centered Design/Human Factors	3
HCO 610	Special Topics: Developing Leadership Presence	3
HCO 605	Concepts & Tools in Value-Based Health Care	3
HCO 608	Capstone Seminar	3
HCO 609	Capstone Project	3
Total Units		**30**

Courses

Visit online course listings to view semester offerings for T92 HCO (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T92&crslvl=5:8).

T92 HCO 601 Introductory Overview of Operational Excellence in Health Care
This introductory course is designed to prepare students for the Master's of Healthcare Operational Excellence program. Students will learn the fundamentals of operational excellence principles and how the organizational complexities, regulatory and economic framework, and nuances of healthcare impact the ability to apply them. Students will research and explore both healthcare and non-healthcare examples of performance improvement and operational excellence efforts within different organizations and from different stakeholder perspectives. Throughout the course, students will gain an understanding of how the various methods, both social and technical, can play an integral role in achieving operational excellence, and how to identify and mitigate challenges and barriers. Specific methods will include facilitating teams, change management, lean, six sigma, project management and the importance of principle-based deployments rooted in changing behaviors and transforming culture. By completing this introductory overview course, students will understand the level of personal transformation in mindset and skills that will be necessary in order to successfully impact the changes needed for health care operational excellence.
Credit 3 units.

T92 HCO 602 Facilitation Skills/Change Management
This course integrates strategy and organizational due diligence with facilitation and change management strategies. By examining the relationship between employees, teams, and organizations, students will explore each level and practice assessing and facilitating team processes to maximize productivity and results for members and stakeholders. The course addresses how to get things done when

teams lack leadership or authority. Supporting topics include how to build teams, how to manage meetings, how to build relationships beyond the team, and how to keep teams effective over their life span. Students will learn processes of change and the techniques of change to apply to various types of organizations while using useful design frameworks for facilitation.
Credit 3 units.

T92 HCO 603 Lean Healthcare Concepts, Tools and Lean Management Systems
Students will learn and apply core Lean tools including Value Stream Mapping, 5S, Visual Management, Standard Work, JIT, Push/Pull, Error Proofing, and Daily Management. Critical to applying Lean effectively, participants will also learn how to plan and lead Rapid Improvement Events and other group activities and tactics. This program has been adopted by BJC executive leadership and is identified as a core competency for transformational efforts. Students will also learn the essential elements of a Lean Management System and how to accomplish sustainable results and the development of a continuous improvement culture.
Credit 3 units.

T92 HCO 604 Six Sigma Concepts and Tools
This course is designed to teach the tools associated with the five DMAIC phases: Define, Measure, Analyze, Improve and Control. Some of the tools considered for inclusion are Critical to Quality Matrix (CTQ), Failure Modes Effectiveness Analysis (FMEA), Statistical Analysis, Contingency Tables, Hypothesis Testing, Confidence Intervals, Correlation & Regression, Analysis of Variation (ANOVA), Pareto Analysis, Statistical Process Control (SPC), Measurement Systems Analysis (MSA), Data Collection, Time Studies, Root Cause Analysis (RCA), Fishbone Diagramming, Cost of Poor Quality (COPQ), SIPOC, Detailed Process Mapping, Cause and Effect tools, and Design of Experiment (DOE).
Credit 3 units.

T92 HCO 605 Concepts & Tools in Value-Based Health Care
This course provides an overview of the evolution of the healthcare delivery landscape and an understanding of how coordination of the fragmented components of the healthcare value chain can enhance the quality of care, reduce cost, and improve patient experience and outcomes. Students will learn about different value-based care constructs and disruptive forces in healthcare. Students will learn practical applications of performance improvement tools in value-based care. Specific areas of focus include clinical innovation, alignment structures, payment reform, quality improvement, and information technology.

Credit 3 units.

T92 HCO 606 Innovation Science and Human-Centered Design/ Human Factors
This course is intended to introduce the student to the concept of "design thinking" as well as the process for innovating. It is dependent on an individual's ability to observe what people are actually doing and how they are doing it. It also requires an iterative process for understanding, synthesizing, ideating, prototyping, testing, and implementing. Emphasis will be placed on how to build stakeholder/ user personas and requirements as well as how to map their emotional experience with a process to gain more insights than a quantitative analysis alone would provide. Healthcare needs a "human-centered" design approach to navigate the blurring of lines between product and service, provider and patient. Designers of processes, methods, and systems now must take the needs of the entire world -- including the environment -- into account. Human factors will need to be applied during the iterative process to account for human factors and the parameters of users and uses.
Credit 3 units.

T92 HCO 607 Project Management in Healthcare
This course is a practical experiential orientation to project management processes, including relevance and application. Students will be exposed to the art of project leader competencies and emotional intelligence in addition to the science of traditional project management methodologies in a healthcare setting. Participants will engage in project initiation, including strategic organizational alignment, concept of why, and charter development. Project planning will include scoping, elicitation of stakeholder requirements, work breakdown structure, scheduling, cost, quality, resources, communications and risk management. Healthcare-related project management and execution will be the focus of practical application, along with other relevant examples from outside of the healthcare industry. Learners will apply the management of triple constraint (time, cost, schedule) as well as skills to align executive sponsor(s) and key stakeholders. Exposure will include disciplines of execution, monitoring, and controlling and closing processes. The course will integrate core concepts of initiating change, portfolio and program management, business analysis, performance improvement, and effective facilitation in a healthcare setting.
Credit 3 units.

T92 HCO 608 Capstone Seminar
This course integrates the learning from all disciplines and subject matter presented in the Master's in Healthcare Operational Excellence program to complete a comprehensive, practical project in a healthcare-related organization. It will include a summary of the key topics covered within the program and how these apply to student's projects. The course will also focus on leading organizational change and fostering a culture of continuous improvement in healthcare and related service organizations into the future.
Credit 3 units.

T92 HCO 609 Capstone Project
The capstone project incorporates operational excellence principles, the lean management system, rapid cycle improvement methods, data analysis, change management, facilitation, project management and healthcare cultural issues, thereby integrating the lessons learned through the course work to demonstrate students' mastery of operational excellence in healthcare. Students will work in multidisciplinary teams, delivering a final project that applies their cumulative course work within a context of real industry work.
Credit 3 units.

T92 HCO 610 Special Topics in Healthcare Leadership
This special topics course will explore emerging best practices in healthcare leadership.
Credit 3 units.

T92 HCO 699 Applied Research Study
Applied Research Study (ARS) is an advanced, project-based course designed to allow students to develop in-depth knowledge and further their education building on the education offered in the Programs. Applied research is a type of examination looking to find practical solutions for existing problems. These can include challenges in the workplace, education, and society. Students collaborate with an adjunct faculty advisor to collect data. Findings are applicable and may be implemented upon completion of a study. Applied research focuses on answering one specific applied research question for a client or sponsor. Applied Research Study must have prior approval of a faculty sponsor and the Program Director.
Credit 3 units.

Graduate Certificates

Graduate Certificate in Construction Management

The Graduate Certificate in Construction Management is a 15-unit program designed for working professionals. Students will be prepared for every aspect of leading a construction project or organization. Created for any professional of the built environment, our curriculum incorporates traditional themes like cost, time, risk and quality management with multidisciplinary topics such as business, finance, ethics and law. Lecture and lab-based education provides students with an environment for practical application utilizing best practices that address current issues and developments in the industry.

Graduate Certificate: 15 units, 10-15 months to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/construction/index.html

Faculty

Program Director

Steve Bannes
Director of Graduate Studies, Construction Management
Professor of Practice
MS, Education, Southwest Baptist University
BS, Construction Engineering & Management, Southern Illinois University Edwardsville

For a list of our program faculty (https://sever.wustl.edu/faculty/#construction_management), please visit our website.

Requirements

Graduate Certificate in Construction Management

In order to earn the certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the certificate.

Code	Title	Units
Required: 15 units		
CNST 523A	Construction Cost Estimating	3
CNST 572	Legal Aspects of Construction	3
CNST 573	Fundamentals in Construction Management	3
CNST 574C	Construction Project Planning and Scheduling	3
ETEM 587	Communication Excellence for Influential Leadership	3

Courses

Visit online course listings to view semester offerings for T64 CNST (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T64&crslvl=5:8).

T64 CNST 523A Construction Cost Estimating
Construction cost estimating explores the application of cost estimating principles and estimating within a project management framework in conjunction with scope definition, quality control, planning and scheduling, risk management and loss prevention techniques, local conditions, information and communication, and working relations with stakeholders. Using a single building project, the course introduces the application of basic quantity surveying and estimating principles using a methodical approach with suggested check lists and techniques for arriving at a reliable cost estimate including direct, indirect, and contingency costs and profits. Student's estimating efforts culminate with a competitive bid day scenario. Prerequisite: T64 573 or permission of instructor.
Credit 3 units.

T64 CNST 572 Legal Aspects of Construction
A survey of the legal problems of the construction manager, including but not limited to liability in the areas of contracts, agency, torts, insurance, bad judgment and oversight.
Credit 3 units.

T64 CNST 573 Fundamentals in Construction Management
In this course, students will be exposed to the overall construction process from initial concept through startup of the completed facility. The focus is to provide familiarization of the construction and contracting process and potential involvements by construction managers in the planning, design, construction, and post construction phases. Additional topics are introduced to provide a foundation which will prepare students for future construction management coursework. Case studies and industry examples are used throughout the course to authenticate the lectures and assignments.
Credit 3 units.

T64 CNST 574C Construction Project Planning and Scheduling
Project planning and scheduling process utilizing current techniques including critical path analysis for effective and logical scheduling of construction projects. Identification of project activities and their relationships; schedule development, analysis, and updating; relationship of project costs and resources to the schedule; legal implications; effective communication of schedule information; development of procedures to monitor actual field progress; computer application in project scheduling. Prereqs: T64 CNST 573 or permission of instructor.
Credit 3 units.

T55 ETEM 587 Communication Excellence for Influential Leadership
Exceptional communicators become extraordinary leaders. This course will guide students to learn to exceptionally communicate their message by applying refined nuances that inspire and transform those with whom they converse. Through a proven communicative process, students will acquire skills necessary to differentiate them as leaders. Students will learn how to communicate across a variety of settings using strategies that result in clear, vivid, and engaging exchanges. Students will practice: storytelling; creating and using clear visuals; engaging listeners; demonstrating passion when speaking; responding to questions with clarity and brevity, and, using their distinctive voice as a leadership asset. Each student will learn how to assess his or her own communication capabilities, adjust to different listeners, and how to evaluate speaker effectiveness and provide valuable feedback to others. Video recordings will be used to demonstrate incremental communicative changes throughout the course, and to show how these strategies bring about outstanding leadership.
Credit 3 units.

Graduate Certificate in Cybersecurity Management

Securing an organization's data requires a combination of technical skills, innovative concepts and managerial acumen. The Graduate Certificate in Cybersecurity Management at Washington University is a 15-unit part-time program designed for working professionals. This program was developed with one critical goal: to educate professionals about how to manage the people and resources required to perform these tasks and to lead the cybersecurity functions of various organizations.

The curriculum provides students with the knowledge needed to protect from, defend against, respond to and recover after cyber threats. Graduates of this certificate program will be equipped to design, engineer and assess global cybersecurity problems while maintaining the vision and strategy of the enterprise.

Graduate Certificate: 15 units, 10-15 months to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/cybersecurity/index.html

Faculty

Program Director

Joe Scherrer (https://sever.wustl.edu/faculty/Pages/Joe-Scherrer.aspx)
Executive Director, Professional Education
Director, Cybersecurity Strategic Initiative
Program Director, Graduate Studies in Cybersecurity Management
Doctor of Liberal Arts, Washington University in St. Louis, 2023 (projected)
MS, Business Administration, Boston University
MS, Information Systems Management, Air Force Institute of Technology
MS, National Security Studies, Naval War College
MS, Strategic Studies, Air War College
BS, Electrical Engineering, Washington University in St. Louis

For a list of our program faculty (https://sever.wustl.edu/faculty/#cybersecurity_management), please visit our website.

Requirements

Graduate Certificate in Cybersecurity Management

Total units required: 15

In order to earn the certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the certificate.

Code	Title	Units
Required: 15 units		
CYBER 560	Cybersecurity Technical Fundamentals	3
CYBER 561	Oversight for Excellence: Cybersecurity Management and Governance	3
CYBER 562	Efficient and Effective Cybersecurity Operations	3
CYBER 566	Cybersecurity Risk Management	3
CYBER 567	The Hacker Mindset: Cyber Attack Fundamentals	3

Courses

Visit online course listings to view semester offerings for T83 CYBER (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T83&crslvl=5:8).

T83 CYBER 560 Cybersecurity Technical Fundamentals
This course presents a comprehensive survey of cybersecurity technology, including basic theory and concepts. Students will gain hands-on familiarity with cybersecurity technology through lab exercises, in-class studios, and scenarios. Topics covered include

security considerations surrounding operating systems, the web, email, databases, wireless technology, the cloud, and the Internet of Things. Also addressed are cryptography, secure software design, physical security, and human factors in cybersecurity.
Credit 3 units.

T83 CYBER 561 Oversight for Excellence: Cybersecurity Management and Governance
This course takes a comprehensive approach to the management of the organizational cybersecurity function. It also explores the principles of information technology governance. Course work provides a deeper understanding of best practices for managing cybersecurity processes and meeting multiple needs of enterprise management by balancing business risks and operational and technical imperatives. Toward this end, the course addresses a range of topics necessary for success, including the elements of and how to establish a governance program, cybersecurity management frameworks, developing and implementing a cybersecurity strategy, deploying cybersecurity policy and controls, ensuring standards and regulatory compliance, functional and budgetary advocacy, interfacing with the C-suite and board, and talent acquisition and development.
Credit 3 units.

T83 CYBER 562 Efficient and Effective Cybersecurity Operations
In this course, students will gain understanding of what it takes to manage the people, process, and technology for effective and efficient day-to-day cybersecurity operations. Using the Cybersecurity Operations Center (CSOC) as the fundamental exemplar, students will learn the functions and processes that comprise a typical CSOC with an underlying focus on continually optimizing operations and processes to ensure agility and performance. Students will examine options for structuring the CSOC and core CSOC functions and processes such as threat intelligence; monitoring, detection, and threat assessment; vulnerability management; incident response; prevention, including awareness training; partner and third-party coordination; analytics, metrics, and reporting; training; and CSOC technologies and instrumentation.
Credit 3 units.

T83 CYBER 566 Cybersecurity Risk Management
In this course, students will gain deeper appreciation of the challenges faced by enterprises when addressing cybersecurity risks. The course will cover the evolution of cyber threats, including attacker methods and their targets across different industries. Students will be able to understand the differences between enterprise, operational and cybersecurity risk management and the role that each play (or should play) in managing risks to an organization. Students will gain technical understanding of industry-leading frameworks (COSO, ISO, NIST, FAIR) and become conversant with their strengths and weaknesses as well as the applicability and practicality of their implementation.
Credit 3 units.

T83 CYBER 567 The Hacker Mindset: Cyber Attack Fundamentals
This course is designed to provide an introductory understanding of how offensive security techniques practically operate. During this course, students will use hacking techniques to compromise systems, collect data, and perform other tasks that fall under the generally understood use of the term "hacker." These techniques will be related to risk-based defensive security practices, with a view toward enhancing the student's understanding of what it takes to be a successful "defender." By the conclusion of the course, students will have a baseline technical understanding of hacking techniques; they will have executed offensive security operations and increased their technical understanding of what it takes to deal with cyber threats.
Credit 3 units.

Graduate Certificate in Engineering Management

The competitive Engineering Management program bridges the gap between technology and business by providing students with the technical expertise and leadership skills needed to advance their careers. The 15-unit Graduate Certificate in Engineering Management is available for part-time, working professional students.

This program brings together Washington University faculty and industry-leading experts to help students learn to strategize, lead, make informed decisions, manage financials, and leverage both existing and emerging technology. The courses prepare individuals to utilize common management tactics across all of the engineering disciplines.

Graduate Certificate: 15 units, 10-15 months to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/engineering/index.html

Faculty

Program Director

John Bade
Director of Graduate Studies, Engineering Management and Project Management
PhD, Engineering, Missouri University of Science & Technology
MBA, Saint Louis University
ME, Missouri University of Science & Technology

For a list of our program faculty (https://sever.wustl.edu/faculty/#engineering_management), please visit our website.

Requirements

Graduate Certificate in Engineering Management

Total units required: 15

In order to earn the certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the certificate.

Code	Title	Units
Required: 15 units		
ETEM 504	Engineering Management & Financial Intelligence	3
ETEM 506	Technology Strategy & Marketing	3

ETEM 510	Understanding Emerging & Disruptive Technologies	3
ETEM 582	Human Performance in the Organization	3
or ETEM 581	Leading in a Technology-Rich World	
ETEM 530	Project Planning Methodologies	3

Courses

Visit online course listings to view semester offerings for T55 ETEM (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T55&crslvl=5:8).

T55 ETEM 504 Engineering Management & Financial Intelligence
Discover the full picture of how business works within the organization. This course walks the student through the complete business cycle -- the roles the various functions play in a business operation as well as how information is used to make business decisions (e.g. financial data, marketing data, production data, economic data). To bring these learnings to life, this course also uses management simulation games and classroom competitions. Includes strategy, product planning and management, sales and support, research and development, manufacturing and supply chain, with particular emphasis on accounting, finance and the use of financial statements.
Credit 3 units.

T55 ETEM 506 Technology Strategy & Marketing
Learn the art and science of technology-rich strategy and marketing. Every business rises and falls on the value it brings to the customer and the value it simultaneously brings to the business itself. The engineer that understands and can communicate strategy and marketing is powerful! Business, technology and research budgets are allocated based on this value proposition, whether the commercialization or operationalization of the technology is 1 year out or 10 years out.
Prerequisite: T55 504.
Credit 3 units.

T55 ETEM 510 Understanding Emerging & Disruptive Technologies
We live in an era of rapid technology innovation and disruption. Blockbuster was the darling of Wall Street in 2004 and filed for bankruptcy in 2010. Blockbuster CEO in 2008: "Neither Redbox nor Netflix are even on the radar screen in terms of competition." Blockbuster is not alone in their blindness. Microsoft laughed off the first i-phone, and laughed off Google. IBM laughed off the first personal computer. These should be a horrible warning to all business leaders. Numerous technologies are threatening disruption today: block chain, Internet of Things (IoT), artificial intelligence, autonomous vehicles, unmanned aerial vehicles (UAVs), 3D printing, 5G wireless networks, gene editing. Understanding what they are and how they might disrupt will make or break countless companies in the coming years.
Credit 3 units.

T55 ETEM 530 Project Planning Methodologies
Build your expertise with today's critical project management methodologies in our fast-paced world. Variations of waterfall are widely used in industry, but new uses of agile are being discovered every day, both inside and outside of software-based organizations. This course exposes the student to the fundamental and emerging techniques and tools used to manage successful projects of various sizes and complexity -- managing cost, schedule, quality, risk, solution and requirements -- while adapting to today's fast-paced and uncertain business environment. The primary focus of this course is on agile.
Credit 3 units.

T55 ETEM 581 Leading in a Technology-Rich World
Leadership has fundamentally changed from top-down, autocratic and task-focused to collaborative and people-focused in just a few generations. Great senior leaders now get their people to do the greatest things. They must constantly learn, think innovatively, move and adapt very quickly, and collaborate over short and long distances. Students will learn new leadership skills, explore their individual leadership styles, and discuss the senior leadership challenges in an evolving tech-rich world.
Credit 3 units.

T55 ETEM 582 Human Performance in the Organization
Have you ever wondered why some careers soar and others stall? Why you find it easy to build relationships with some people - but not others? Why some teams function well and consistently outperform others? Are you curious about what kind of manager you are, or will be? Do you want to know more about how organizations decide who to hire and who to promote? Human Performance in the Organization is designed to help you answer these questions. The content is a mix of relevant theory, personal reflection, and practical application. Our goal is to understand human performance at all levels of the organization. Topics include performance and career management; negotiation and influence; power and politics; mentoring and coaching; high-performance teams; conflict management; talent development and succession planning; and change management.
Credit 3 units.

Graduate Certificate in Health Care Operational Excellence

Managing health care systems today is more than process efficiencies and quality assessment. At every level and dimension, it takes an interdisciplinary approach to get it right. The Graduate Certificate in Health Care Operational Excellence (HCOE) can help you advance with the knowledge, leadership and skills needed to establish, implement and oversee important process analysis and continuous improvement initiatives in the growing field of health care.

Designed with input from employers, thought leaders, and practitioners, the HCOE program is taught by leading health care professionals, experts and executives. This program provides a solid foundation in the areas of project management fundamentals, navigating organizational change, process improvement, human-centered design, operations and finance, and emerging issues in health care and related service organizations. The program also addresses the more nuanced human factors and topics of personal leadership and resilience.

Graduate Certificate: 15 units, 10-15 months to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/healthcare/index.html

Faculty

Program Director

Leroy Love (https://sever.wustl.edu/faculty/Pages/Leroy-Love.aspx)
Director of Graduate Studies in Health Care Operational Excellence
MS, Missouri University of Science & Technology
BS, University of Missouri-Columbia

For a list of our program faculty (https://sever.wustl.edu/faculty/#health_care_operational_excellence), please visit our website.

Requirements

Graduate Certificate in Health Care Operational Excellence

Total units required: 15

In order to earn the certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the certificate.

Code	Title	Units
Required: 15 units		
HLTHCARE 501	Introductory Overview of Operational Excellence in Health Care	3
HLTHCARE 502	Facilitation Skills/Change Management	3
HLTHCARE 503	Lean Healthcare Concepts, Tools and Lean Management Systems	3
HLTHCARE 504	Six Sigma Concepts and Tools	3
HLTHCARE 507	Project Management in Healthcare	3

Courses

Visit online course listings to view semester offerings for T71 HLTHCARE (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T71&crslvl=5:8).

T71 HLTHCARE 501 Introductory Overview of Operational Excellence in Health Care
This introductory course is designed to prepare students for the Master's of Healthcare Operational Excellence program. Students will learn the fundamentals of operational excellence principles and how the organizational complexities, regulatory and economic framework, and nuances of healthcare impact the ability to apply them. Students will research and explore both healthcare and non-healthcare examples of performance improvement and operational excellence efforts within different organizations and from different stakeholder perspectives. Throughout the course, students will gain an understanding of how the various methods, both social and technical, can play an integral role in achieving operational excellence, and how to identify and mitigate challenges and barriers. Specific methods will include facilitating teams, change management, lean, six sigma, project management and the importance of principle-based deployments rooted in changing behaviors and transforming culture. By completing this introductory overview course, students will understand the level of personal transformation in mindset and skills that will be necessary in order to successfully impact the changes needed for health care operational excellence.
Credit 3 units.

T71 HLTHCARE 502 Facilitation Skills/Change Management
This course integrates strategy and organizational due diligence with facilitation and change management strategies. By examining the relationship between employees, teams, and organizations, students will explore each level and practice assessing and facilitating team processes to maximize productivity and results for members and stakeholders. The course addresses how to get things done when teams lack leadership or authority. Supporting topics include how to build teams, how to manage meetings, how to build relationships beyond the team, and how to keep teams effective over their life span. Students will learn processes of change and the techniques of change to apply to various types of organizations while using useful design frameworks for facilitation.
Credit 3 units.

T71 HLTHCARE 503 Lean Healthcare Concepts, Tools and Lean Management Systems
Students will learn and apply core Lean tools including Value Stream Mapping, 5S, Visual Management, Standard Work, JIT, Push/Pull, Error Proofing, and Daily Management. Critical to applying Lean effectively, participants will also learn how to plan and lead Rapid Improvement Events and other group activities and tactics. This program has been adopted by BJC executive leadership and is identified as a core competency for transformational efforts. Students will also learn the essential elements of a Lean Management System and how to accomplish sustainable results and the development of a continuous improvement culture.
Credit 3 units.

T71 HLTHCARE 504 Six Sigma Concepts and Tools
This course is designed to teach the tools associated with the five DMAIC phases: Define, Measure, Analyze, Improve and Control. Some of the tools considered for inclusion are Critical to Quality Matrix (CTQ), Failure Modes Effectiveness Analysis (FMEA), Statistical Analysis, Contingency Tables, Hypothesis Testing, Confidence Intervals, Correlation & Regression, Analysis of Variation (ANOVA), Pareto Analysis, Statistical Process Control (SPC), Measurement Systems Analysis (MSA), Data Collection, Time Studies, Root Cause Analysis (RCA), Fishbone Diagramming, Cost of Poor Quality (COPQ), SIPOC, Detailed Process Mapping, Cause and Effect tools, and Design of Experiment (DOE).
Credit 3 units.

T71 HLTHCARE 507 Project Management in Healthcare
This course is a practical experiential orientation to project management processes, including relevance and application. Students will be exposed to the art of project leader competencies and emotional intelligence in addition to the science of traditional project management methodologies in a healthcare setting. Participants will engage in project initiation, including strategic organizational alignment, concept of why, and charter development. Project planning will include scoping, elicitation of stakeholder requirements, work breakdown structure, scheduling, cost, quality, resources, communications and risk management. Healthcare-related project management and execution will be the focus of practical application, along with other relevant examples from outside of the healthcare industry. Learners will apply the management of triple constraint (time, cost, schedule) as well as skills to align executive sponsor(s) and key stakeholders. Exposure will include disciplines of execution,

monitoring, and controlling and closing processes. The course will integrate core concepts of initiating change, portfolio and program management, business analysis, performance improvement, and effective facilitation in a healthcare setting.
Credit 3 units.

Online Graduate Certificates

Online Graduate Certificate in Cybersecurity Management

This exclusively online, part-time program was developed for cybersecurity working professionals seeking to advance their leadership skills and to deepen the managerial acumen required to establish, maintain, and develop an effective and efficient cybersecurity enterprise. Students in this 15-unit program will acquire the expertise needed to successfully execute a range of core cybersecurity functions, including governance, operations, incident response, and architecting technical solutions. The program places particular emphasis on business-related skills such as communicating with non-technical line-of-business leaders and peers, speaking the language of business, and strategy formulation and development. Graduates of this program will be well prepared to step into positions of greater responsibility and to make larger and more consequential contributions to their organizations.

Graduate Certificate: 15 units, 10-15 months to complete

Email:	sever@wustl.edu
Website:	https://sever.wustl.edu/degree-programs/cybersecurity/index.html

Faculty

Program Director

Joe Scherrer (https://sever.wustl.edu/faculty/Pages/Joe-Scherrer.aspx)
Executive Director, Professional Education
Director, Cybersecurity Strategic Initiative
Program Director, Graduate Studies in Cybersecurity Management
Doctor of Liberal Arts, Washington University in St. Louis, 2023 (projected)
MS, Business Administration, Boston University
MS, Information Systems Management, Air Force Institute of Technology
MS, National Security Studies, Naval War College
MS, Strategic Studies, Air War College
BS, Electrical Engineering, Washington University in St. Louis

For a list of our program faculty (https://sever.wustl.edu/faculty/#cybersecurity_management), please visit our website.

Requirements

Online Graduate Certificate in Cybersecurity Management

Total units required: 15

In order to earn the certificate, all courses must be passed with a C- or higher. In addition, a student must have a cumulative grade-point average of at least 2.70 over all courses applied toward the certificate.

Course numbers below are subject to change. Please contact the Sever Institute Assistant Director of Academic & Student Services for accurate academic advising information.

Code	Title	Units
Required: 15 units		
CSM 660	Cybersecurity Technical Fundamentals	3
CSM 661	Oversight for Excellence: Cybersecurity Management and Governance	3
CSM 662	Efficient and Effective Cybersecurity Operations	3
CSM 666	Cybersecurity Risk Management	3
CSM 667	The Hacker Mindset: Cyber Attack Fundamentals	3

Courses

Visit online course listings to view semester offerings for T93 CSM (https://courses.wustl.edu/CourseInfo.aspx?sch=T&dept=T93&crslvl=5:8).

T93 CSM 660 Cybersecurity Technical Fundamentals
This course presents a comprehensive survey of cybersecurity technology, including basic theory and concepts. Students will gain hands-on familiarity with cybersecurity technology through lab exercises, in-class studios, and scenarios. Topics covered include security considerations surrounding operating systems, the web, email, databases, wireless technology, the cloud, and the Internet of Things. Also addressed are cryptography, secure software design, physical security, and human factors in cybersecurity.
Credit 3 units.

T93 CSM 661 Oversight for Excellence: Cybersecurity Management and Governance
This course takes a comprehensive approach to the management of the organizational cybersecurity function. It also explores the principles of information technology governance. Course work provides a deeper understanding of best practices for managing cybersecurity processes and meeting multiple needs of enterprise management by balancing business risks and operational and technical imperatives. Toward this end, the course addresses a range of topics necessary for success, including the elements of and how to establish a governance program, cybersecurity management frameworks, developing and implementing a cybersecurity strategy, deploying cybersecurity policy and controls, ensuring standards and regulatory compliance, functional and budgetary advocacy, interfacing with the C-suite and board, and talent acquisition and development.
Credit 3 units.

T93 CSM 662 Efficient and Effective Cybersecurity Operations
In this course, students will gain understanding of what it takes to manage the people, process, and technology for effective and efficient day-to-day cybersecurity operations. Using the Cybersecurity Operations Center (CSOC) as the fundamental exemplar, students will learn the functions and processes that comprise a typical CSOC with an underlying focus on continually optimizing operations and processes to ensure agility and performance. Students will examine options for structuring the CSOC and core CSOC functions and processes such as threat intelligence; monitoring, detection, and threat assessment; vulnerability management; incident response; prevention, including awareness training; partner and third-party coordination; analytics, metrics, and reporting; training; and CSOC technologies and instrumentation.
Credit 3 units.

T93 CSM 666 Cybersecurity Risk Management
In this course, students will gain deeper appreciation of the challenges faced by enterprises when addressing cybersecurity risks. The course will cover the evolution of cyber threats, including attacker methods and their targets across different industries. Students will be able to understand the differences between enterprise, operational and cybersecurity risk management and the role that each play (or should play) in managing risks to an organization. Students will gain technical understanding of industry-leading frameworks (COSO, ISO, NIST, FAIR) and become conversant with their strengths and weaknesses as well as the applicability and practicality of their implementation.
Credit 3 units.

T93 CSM 667 The Hacker Mindset: Cyber Attack Fundamentals
This course is designed to provide an introductory understanding of how offensive security techniques practically operate. During this course, students will use hacking techniques to compromise systems, collect data, and perform other tasks that fall under the generally understood use of the term "hacker." These techniques will be related to risk-based defensive security practices, with a view toward enhancing the student's understanding of what it takes to be a successful "defender." By the conclusion of the course, students will have a baseline technical understanding of hacking techniques; they will have executed offensive security operations and increased their technical understanding of what it takes to deal with cyber threats.
Credit 3 units.

Doctoral Program Information

Doctor of Philosophy

The Doctor of Philosophy (PhD) degree is not only an exploration of the knowledge in a given discipline but also an original contribution to it. To the extent that doctoral education has been successful, the student's relationship to learning is significantly changed. Having made a discovery, developed an insight, tested a theory or designed an application, the PhD recipient is no longer a student but a colleague of the faculty. It is for this reason that the PhD is the highest degree offered by a university.

The core mission of PhD programs at research universities is to educate the future faculty of other research universities and institutions of higher education. Graduates of Washington University participate in research and teaching; they also make valuable contributions to society by applying the analytical and creative skills required for scholarship to careers in the business, government and nonprofit sectors.

Among the critical components the university provides for these purposes are a small and select graduate student body, faculty members dedicated to scholarly work, and the physical facilities needed for research. In these regards, Washington University compares favorably to the finest graduate institutions in the world. However, the key ingredients of PhD completion must be provided by the student: a love of learning and a desire to increase the sum of human knowledge. Motivation and perseverance are prerequisites for success in PhD programs.

Doctor of Science

The Doctor of Science (DSc) degree is conferred in recognition of the candidate's abilities and attainments in some field of engineering. The DSc is a doctorate in science equivalent to a PhD doctoral degree. The departments of Electrical & Systems Engineering and Mechanical Engineering & Materials Science offer both the PhD and DSc doctoral options for graduate students.

The requirements for the DSc are identical to those for the PhD except for the following: (1) the mentored teaching experience is not required for the DSc; (2) the residency requirement for the DSc is limited to 24 units completed at Washington University; and (3) the requirements for research rotations and the time limits for completion of the qualifying exam, proposal, and thesis defense for the PhD do not apply to the DSc.

The DSc is recommended for students who will pursue doctoral studies part-time. Stipend support from grants or contracts is typically not available to DSc candidates.

General Requirements

Candidates for doctoral degrees at Washington University must complete all courses required by their department; maintain satisfactory academic progress; pass certain examinations; fulfill residence and teaching requirements (if applicable); write, defend and submit a dissertation; and file an Intent to Graduate form on WebSTAC (https://acadinfo.wustl.edu).

Engineering-based doctoral degrees require a minimum of 72 units. The doctoral program requires 36 to 48 units of course work and 24 to 36 units of research. The specific distribution decisions are made by the individual programs and departments.

The doctorate can be awarded only to those students whose knowledge of their field of specialization meets contemporary standards. Course work completed more than seven years prior to the date the degree is awarded generally cannot be accepted as satisfying degree requirements. No courses will be accepted toward degree requirements if the course exceeds the 10-year maximum time period unless they are formally approved by the McKelvey Doctoral Committee. In addition, all milestone requirements for the degree must be completed within seven years from the time the student is admitted to a graduate program.

The doctoral degree has a residency requirement of one year. To satisfy the requirement, the student must devote full time for two consecutive semesters to academically relevant activities on the Washington University campus. A limited amount of outside employment may be permitted, but only with the approval of the department or program chairman and/or the dean. Candidates for the Doctor of Philosophy degree and the Doctor of Science degree are required to follow the guidelines of the Office of the Provost and of the McKelvey School of Engineering.

Advisor & Doctoral Committee

Once admitted to graduate standing, each doctoral student will have an advisor appointed by the chair or director of the designated area of specialization. It is the responsibility of the advisor to help the student plan a graduate program.

Each department within McKelvey School of Engineering has its own policy related to the selection of a doctoral committee; therefore, students should consult with their faculty advisor regarding the appointment of their doctoral committee.

Doctoral Qualifying Examination

To be admitted to candidacy for a doctoral degree, the student must pass a comprehensive qualifying examination that may consist of both written and oral portions. The examination is administered by the student's department or program, and the student should consult their advisor for information concerning the scope of the examination and the dates on which it is given. The examining panel will consist of faculty members approved by the department chair or the program director.

Doctoral Dissertation

Doctoral candidates must submit a satisfactory dissertation that involves independent creative work in an area of specialization and that demonstrates an ability for critical and constructive thinking. It must constitute a definite contribution to knowledge in some field of engineering. The research that is the subject of the dissertation must have been performed under the supervision of a member of the faculty of McKelvey School of Engineering. The candidate must defend the dissertation during a final oral examination by an examining committee to be nominated by the advisor and approved by the appropriate dean.

For specific information about preparing the dissertation for submission, candidates should refer to the thesis and dissertation submission procedures on the McKelvey School of Engineering webpage (https://engineering.wustl.edu/offices-services/student-services/graduate-student-services/thesis-dissertation-submission.html).

Each candidate for the doctoral degree must electronically submit a final approved version of their dissertation. The dissertation should include an abstract that embodies the principal findings of the research and that has been approved by the doctoral committee as ready for publication. Such an abstract will be published in Dissertation Abstracts, which announces the availability of the dissertation for distribution.

Administration

Dean's Office
314-935-6350

Department of Biomedical Engineering
314-935-6164

Department of Computer Science & Engineering
314-935-6160

Department of Electrical & Systems Engineering
314-935-5565

Department of Energy, Environmental & Chemical Engineering
314-935-6070

Department of Mechanical Engineering & Materials Science
314-935-6047

Engineering Information Technology
314-933-3333

Engineering Graduate Student Services
314-935-5830

Doctoral Program Policies

To view additional policies for PhD students, please refer to the University PhD Policies & Requirements (p. 23) section of this *Bulletin*.

Admissions

Eligibility

Washington University encourages and gives full consideration to all applicants for admission and financial aid, without regard to race, color, age, religion, sex, sexual orientation, gender identity or expression, national origin, veteran status, disability or genetic information.

McKelvey School of Engineering is strongly interested in recruiting, enrolling, retaining and graduating students from diverse backgrounds. Applications for admission by students from diverse backgrounds to any of our degree programs are encouraged and welcomed. To the greatest extent possible, students with disabilities are integrated into the student population as equal members.

To be considered for admission into a graduate degree program, applicants must hold a bachelor's degree from an accredited institution prior to starting the graduate program. Most of the engineering degree programs require a previous degree in science, technology, engineering or mathematics.

Current engineering graduate students who wish to be admitted into another engineering graduate program must be admitted at least one semester prior to their anticipated graduation semester.

Students may be admitted to study for the PhD degree directly from baccalaureate study or after undertaking other graduate or professional education, whether at Washington University or at another accredited institution.

Application Process

Degree programs set their own application deadlines. Applicants should check deadlines (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/application-process.aspx) through the McKelvey School of Engineering. It is generally advantageous to the applicant to complete the application well in advance of the deadline.

The application (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/default.aspx) is available online through the School of Engineering website. Applications are ready for final consideration after the required items from the application checklist have been submitted.

Please review our application checklist (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html) for details on all materials needed for a complete application.

Admission and financial aid awards are for a specific academic year; students who do not matriculate that year must normally reapply. Admitted students can request a deferral of admission for up to one year, but such special requests require approval of both the admitting program and the admissions office. Applicants to whom admission is not offered may reapply for a future semester.

Admission of International Students

International students considering application to Washington University for graduate study should have a general familiarity with academic practices and university customs in the United States. All international students are required to present evidence of their ability to support themselves financially during graduate study. International students are required to submit valid English proficiency score reports from the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). Tests should be taken in time for results to reach Washington University by the application deadline. Official test scores are required at the time of application.

The English proficiency requirement may be waived during the application process. Please review the waiver eligibility criteria found on our application checklist (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html).

Attendance

Each professor in the McKelvey School of Engineering decides how many absences a student may have and still pass the course. Professors are expected to give reasonable consideration to unavoidable absences and to the feasibility of making up work that has been missed. Students are expected to explain to their professors the reasons for any absences and to discuss with them the possibility of making up missed assignments.

Units and Grades

Credit-conferring grades for graduate students are as follows: A, B, C, or D (these grades may be modified by a plus or minus); S, satisfactory; and U, unsatisfactory (S and U are used for all research units and should be noted at the end of each semester).

Other grades are F, failing; N, not submitted yet; X, final examination missed; and I, incomplete. The mark of I reverts to an F grade after the lapse of one calendar year.

McKelvey uses a 4-point scale for calculating grade-point averages, with A+/A = 4, B = 3, C = 2, and D = 1. A plus (other than with an A grade) adds 0.3 to the value of a grade, whereas a minus subtracts 0.3 from the value of the grade.

Auditing a Course

A student may register for some courses as an auditor. The criteria for a successful audit are determined by the course instructor, and the student should work with the instructor to ensure that these criteria are understood. Generally speaking, the completion of homework and the taking of exams are not required. The grade L signifies a successful audit, and the grade Z signifies an unsuccessful audit. Neither grade affects a student's grade-point average, and the course's units do not contribute to the student's total cumulative degree-seeking units. Audit courses do not count toward any degree, nor do they count toward full-time status determination. They do count toward the 21-unit cap per semester, and audit units are charged at the standard full-time or part-time per-unit rate. Class attendance is normally required to earn a grade of L; unsatisfactory attendance will result in a grade of Z.

Incomplete Grades

The grade I (incomplete) indicates that the work of a student has been generally acceptable but that extenuating circumstances led to certain requirements not having been met. The grade of X is recorded when a student is absent from a midterm or final examination because of illness or other unavoidable reason, provided the work has been otherwise satisfactory.

Grades of X and I must be removed no later than one calendar year after a student returns in residence. On failure to make up an X or I grade, the student will not receive credit for the course, and the grade will be changed to F unless the student has been explicitly excused by the associate dean.

A student should **not** re-enroll in a class to complete an I grade. Enrolling in the class a second time invokes the Course Retake Policy (http://bulletin.wustl.edu/undergrad/engineering/policies/#repeating).

Course Retake Policy

McKelvey graduate students may choose to retake a course with the permission of their advisor. If a course is repeated, only the second grade is included in the calculation of the GPA. Both enrollments and grades are shown on the student's official transcript. The symbol R next to the first enrollment's grade indicates that the course was later retaken. Credit toward the degree is allowed for the latest enrollment only. The R option may be invoked only once per course, and the original grade option must be retained.

Student Grievance

From time to time, students may feel that they have legitimate complaints regarding academic matters or an interaction with a faculty member. It is important that students and faculty have a common understanding of how such complaints may be expressed and resolved. Students with complaints regarding academic matters should initially seek resolution from their faculty advisor, then from their director of graduate studies, and finally from the chair of their degree program. Complaints that remain unresolved may be addressed to the Associate Dean of Graduate Student Services. The final court of appeal for all doctoral students in the school is the Vice Dean of Research and Graduate Education. Washington University policies state that members of the university community can expect to be free from discrimination and harassment. Students, faculty, staff and outside organizations working on campus are required to abide by specific policies prohibiting harassment. An allegation of discrimination or harassment may be appealed to the Vice Chancellor for Human Resources, who will determine whether to convene the Title IX Grievance Committee to hear the case.

Additional Course Information

To count toward a graduate degree, courses must be offered at the graduate level, taken for a grade, and approved in advance by the student's advisor and program as eligible to count toward the student's degree. Depending on the program, graduate-level work begins with courses numbered at the 400 or 500 level. Audited courses and courses taken on a pass/fail basis cannot be counted toward the degree. Students should consult their advisors regarding these options.

All McKelvey doctoral programs require a minimum of 72 units of a combination of course work and research units to be completed for a degree. Students should consult their program handbooks for courses specific to their program.

Master's Degrees

Doctoral students who have not previously earned a master’s degree in the same field as their PhD may earn the MS on the way to their PhD. Those who wish to obtain a master’s degree must first discuss this with their research advisor. Once they have the approval of their research advisor, they should contact the director of the master’s program in which they plan to pursue the degree and ask for formal admission to the program. The MS must be added at the end of a semester and prior to filing an intent to graduate. An MS program will not be opened midsemester. Doctoral students should note that transferring courses into a master’s program is done on a course-by-course basis and should consult the master’s handbook for that procedure.

Transfer Credit

A maximum of 24 units of graduate credit earned at institutions other than Washington University may be applied toward the PhD degree, and a maximum of 48 units may go toward the DSc degree. Transfer credit must be recommended by the advisor, department or program chair and approved by the appropriate registrar with receipt of an official transcript. No graduate courses carrying grades lower than B can be accepted for transfer toward any graduate degree.

Students who have previously earned a Master's degree from Washington University may be eligible to count all graduate-level credit earned for the Master's degree toward their doctoral degree. Eligible courses are at the discretion of the program director.

Students transferring to McKelvey with a faculty member may be eligible to transfer more than the 24-unit maximum at the discretion of the program director.

Registration and Enrollment Policies

Full-Time and Length of Enrollment

Students admitted to a PhD program in the McKelvey School of Engineering must maintain full-time continuous enrollment throughout the approved length of the program. McKelvey PhD programs are to be completed within six years under normal conditions. During those years, students will be considered full-time with one or a combination of the following enrollments: registered for 9 or more course units (including doctoral research units); or registered in EGS 9000 Full-Time Graduate Research/Study or EGS 9001 Full-Time Graduate Study in Absentia (see below). These courses indicate the student's full-time engagement in research or academic writing and should be used once a student has completed the 72-unit requirement for the program. PhD students who are not registered as above may find themselves in a part-time status and could be in jeopardy of the loss of certain benefits or be in violation of their visa status. Part-time enrollments will be permitted only in extraordinary circumstances. EGS 9002 Full-Time Graduate Student Extension (see below) should be used for enrollment in circumstances requiring a seventh year.

In-Absentia Enrollment

During a student's period of regular registration, they may have a need or opportunity to study away from Washington University. Recommendations from departments for students' registration in absentia will be considered by the school on a case-by-case basis. If approved, the student will be registered for EGS 9001 Full-Time Graduate Study in Absentia. Students may be allowed to register for EGS 9001 for up to four consecutive or nonconsecutive fall/spring semesters. Semesters in which a student is registered in absentia are counted as part of the student's program length.

Leaves of Absence (Medical and Personal)

A student may request and be approved for a leave of absence during their regular registration period if they are not registered in absentia. Personal leaves of absence must be approved by the degree program and may be allowed for up to one year at a time. Extensions must be reapproved. Medical leaves of absence require authorization from Habif Health and Wellness Center at the beginning of the leave and again in order to return from the leave. At the end of any leave of absence, a student is reinstated under the conditions prevailing at the time the leave was granted.

Approved leaves of absence are not counted as part of a student's program length and will not be approved for semesters beyond the stated program length, including enrollment extension. While on a leave of absence, the student is not registered and has no student status at Washington University, including financial support. Students who begin a leave during a semester will be dropped from all course registration for that semester and will receive no course credit for work completed during that semester prior to the leave. Taking a leave may therefore adversely affect loan deferment, visa status, the right to rent university-owned housing, and so on. Most visa types would prevent international students from remaining in the United States while taking a leave of absence; such students should consult the Office for International Students and Scholars (http://oiss.wustl.edu) as well as their faculty advisor.

The continuation of student health insurance and access to the Habif Health and Wellness Center depends on various factors as to the kind of leave (medical or personal), the length of time the student has already been covered during the current insurance year, and the student's location during the leave. Students should consult the Habif Health and Wellness Center website (http://shs.wustl.edu/Pages/ default.aspx) for current policies related to leaves of absence; these policies may change annually if insurance carriers change.

Enrollment Extension

Students may be permitted to register for one additional year beyond their program length when approved by their department or program. These students will be registered in EGS 9002 Full-Time Graduate Study Extension, which confers full-time enrollment status. Students registered for EGS 9002 may or may not receive financial support, but they are eligible to receive other benefits available to full-time PhD students, including health insurance and wellness fee subsidies.

Degree Candidacy Extended

Upon the recommendation of their departments or programs, students who do not complete their PhD degrees within their program length and potential one-year enrollment extension may remain doctoral candidates for up to five years. Departmental recommendations and Associate Dean of Graduate Student Services approval are required for each year of extended degree candidacy. Extended degree candidates are not registered for any courses, have no enrollment status, and receive none of the benefits available to registered Washington University students, including student loan deferment. Students who do confer their degrees within the five-year extension period do so from a closed program status and do not re-enroll.

Reinstatement

Graduate students who do not register in one of the scenarios described under the full-time enrollment policy may have to apply for reinstatement if they wish to re-enroll at a future time. For reinstatement information, students should contact Graduate Student Services at 314-935-5830 or eng-gradstudserv@wustl.edu. Students seeking reinstatement may be required to pay a reinstatement fee, take special reinstatement examinations, and repeat previous work if their previous work fails to meet contemporary standards. Doctoral candidates who apply for reinstatement may be required to repeat qualifying examinations.

Withdrawal

Students wishing to withdraw from their programs must give notice in writing to the Director of Graduate Studies for their program. The program should provide notice to the McKelvey registrars of the withdrawal and the effective dates on which to drop enrollment and financial support.

Academic Progress, Probation, and Suspension

Satisfactory Academic Progress

Satisfactory academic progress for students in PhD programs is monitored by the school as well as by the degree program. Failure to maintain satisfactory academic progress may result in a student's immediate dismissal or in their placement on academic probation for the ensuing year. Most financial awards — and all federally funded awards — are contingent on the maintenance of satisfactory academic progress. The following are minimal standards of satisfactory academic progress for PhD students; students should consult their specific program handbooks as they may have stricter and/or additional standards but may not directly conflict with the below:

1. Students are expected to proceed at a pace appropriate to enable them to finish within the time limits and milestone markers of their program. Students are expected to have completed all PhD requirements except for the dissertation by no later than the end of the fourth year of full-time graduate study.
2. Students are expected to maintain a cumulative grade-point average of at least 3.0.
3. Students are expected not to carry at one time any more than 9 credit units for which the grades of I (incomplete), X (final examination missed), or N (not yet submitted) are recorded.
4. Students must satisfactorily pass the qualifying exam process as identified by their program by the time frame stated in their program handbook.
5. Students must identify a research mentor by the time frame identified in their program handbook.
6. After four years of full-time graduate study, doctoral students who cannot identify three faculty members who are willing to serve on their Research Advisory Committee are not considered to be making satisfactory academic progress. The Title, Scope and Procedure form must be filed before the fifth year in order to identify the membership of the student's Research Advisory Committee.
7. Students may take up to six years to complete the PhD, depending on the program. A one-year extension is available if circumstances warrant (see "Degree Candidacy Extended" above). Extensions are obtained by application of the student to the degree program and approved by the school.

Probation for Academic Reasons

Except for circumstances justifying immediate dismissal, a student cannot be dismissed on the basis of academic performance without the opportunity to return to good standing during an identified period of probation. The purpose of probation is to do the following: (1) to explicitly warn the student of their status; (2) to provide the student with clear guidelines regarding the performance that will be necessary to return to good standing; and (3) to provide the student with reasonable time to meet these expectations. To meet these objectives, probation normally should be designated for a minimum of three months. When the probation criteria involve course work, then the probation period would normally correspond to the semester's duration. A student on probation must receive a detailed letter from the Director of Graduate Studies stating the reasons for the probation and explicitly identifying the steps necessary for the student to return to good standing by the end of the probation period. A copy of this letter should be sent to the Associate Dean of Graduate Student Services. If a student does not meet all criteria for good academic standing but the department does not wish to place the student on probation, an appeal for this exception can be made to the Vice Dean of Research and Graduate Education.

The explanation of academic performance issues leading to probation should be specific (e.g., low GPA, failed exam) and contain a clear statement of what must be done within a specified period of time in order for the student to return to good standing. This includes probation associated with faculty judgments of research potential, timely progress toward the degree, teaching performance, or professional activities. The expectations will be consistent with those held for all students in the program. They must be communicated in writing (as stated above), accompanied by the opportunity to meet with the Director of Graduate Studies or designated departmental faculty representatives for a clarifying discussion, and copied to the Associate Dean of Graduate Student Services. If the student does satisfactorily meet the requirements of the probation, a written notice of reinstatement, including the date that the student has returned to good standing, will be provided to the student. Students may be reinstated before the end of the probation period if they have met the requirements for reinstatement. Copies of any letters or e-mails to the student as well as summary notes of discussions with the student regarding the student’s placement on probation should be placed in the student’s record, which the student has the right to review.

If the student does not meet the requirements of the probation by the specified time and the program recommends dismissal, the program will send a request for dismissal and a draft of the dismissal letter to the Associate Dean of Graduate Student Services, along with copies of all previous communications and/or warnings. The draft dismissal letter will include the grounds for dismissal, the effective date of dismissal, and advice to the student that voluntary withdrawal from the program is an option. All academic dismissals require approval by the Vice Dean of Research and Graduate Education. If the student is an international student on a visa, the program should consult with the Office of International Students and Scholars prior to drafting the dismissal letter. It is often advisable for an international student to withdraw ahead of a dismissal to avoid an adverse impact on their future entry to the United States.

At the end of a first probation, the student may be (1) returned to good standing; (2) placed on a second consecutive probation; or (3) dismissed from the program. A second consecutive probation must be accompanied by a new letter identifying the steps required to return to good standing. While the purpose of the probationary period is to provide the student with time to improve, the decision of the program at the end of a probationary period could involve immediate notification of dismissal. At the end of a second continuous probation, the student will be either returned to good standing or dismissed.

A third probation will be allowed only if it is not continuous. A fourth probation will not be allowed. A student whose performance would result in a fourth probation will be dismissed immediately. A leave of absence cannot be used by a student to delay or nullify the consequences of a third consecutive or fourth probation.

Each program must have a standard procedure (e.g., a graduate advisory committee) to manage decisions regarding placement on probation, removal from probation, recommendations for dismissal after a probationary period, and recommendations for immediate dismissal due to extreme underperformance. The procedure for managing such decisions must be applied to all students in the program and cannot be managed solely by an individual faculty member, including the student's research mentor, although the input provided by the research mentor may play a key role in the process.

Stipend support should continue during a probationary period unless the student is failing to meet the basic expectations of their position (e.g., repeatedly misses classes or is repeatedly absent from the lab and fails to carry out lab assignments). If a program or school decides to suspend stipend support under these circumstances, the student must be given a minimum of two weeks' notice prior to the withholding of such support. If the student's performance improves and they begin meeting the basic expectations of the program, stipend support should resume at that time. During all probationary semesters, tuition remission will remain as offered at initial enrollment.

The appeal of probation or dismissal by a student should follow the guidelines for Student Grievance Procedures in that it should begin at the most local level. In cases of probation or dismissal, a student may appeal within 14 calendar days to the department chair or another designated faculty representative or committee beyond the Director of Graduate Studies or the Graduate Advisory Committee, consistent with department or program procedures.

Appeals of probation end with the Chair of the department or program (i.e., placement on probation cannot be appealed to the Vice Dean of Research and Graduate Education). In cases where there is a perceived conflict of interest with the Chair or the Director of Graduate Studies, another member of the department can be designated to address the appeal process for probation or dismissal.

Dismissal for Academic Reasons

Academic dismissal is distinct from withdrawal (initiated by the student), deactivation of a student's record by a failure to register, and dismissal or other sanctions associated with the University Academic and Professional Integrity Policy or the University Student Judicial Code. Dismissals are recommended by the degree program and are not final until approved by the Vice Dean of Research and Graduate Education. Students may be dismissed immediately for extreme academic underperformance (see "Satisfactory Academic Progress"). Students who encounter personal situations that contribute to academic underperformance during a semester should be informed of the option to request a leave of absence rather than continuing enrollment with poor performance. The ability to complete mentored teaching responsibilities is not a sufficient basis for remaining enrolled.

Most academic difficulties are not of the severity associated with immediate dismissal. The faculty are also responsible for evaluating the ability of the student to identify and undertake an original scholarly project at the level of excellence expected for a Washington University PhD and for determining whether the student is making timely progress toward completion of the degree. The program may place a high value on the quality of performance in mentored teaching and other professional activities. The judgment of the faculty on these issues can lead to academic dismissal for students who meet other criteria for good academic standing. Departments are expected to maintain written guidelines that help students understand the major categories of expectations for satisfactory progress. Such guidelines should be provided to students at the beginning of their academic program and reviewed with students on a regular basis.

For academic dismissal decisions, a graduate student may submit a final appeal of the dismissal to the Vice Dean of Research and Graduate Education. Appeal requests must be initiated at the appropriate level within 14 calendar days of formal notification of probation or dismissal, and appeals to the Vice Dean must be made within 14 calendar days of a decision by the Chair of the department to uphold a student's dismissal. Responses to appeals generally occur within the next 14 calendar days after the appeal is requested. Stipend support is discontinued at the time the student is notified of dismissal. The student is not eligible to receive stipend support during an appeal of dismissal; however, if the appeal is upheld, the student is eligible for stipend support covering the period of the dismissal appeal process. Students who have chosen to withdraw from their program or department (as opposed to taking an authorized leave) cannot appeal or seek reconsideration of this decision.

Satisfactory Academic Progress for Title IV Financial Aid

Federal regulations require that students receiving federal Title IV financial aid maintain Satisfactory Academic Progress (SAP). The minimum GPA requirements needed to maintain eligibility for SAP are dictated by the specific program of study. In each case, per the requirements of 34 C.F.R. 668.34(a)(4(ii), the federal student aid program requires a minimum of a C average to maintain eligibility for aid, but an individual degree or certificate program may have a higher minimum GPA for federal SAP.

SAP is evaluated annually at the end of the spring semester. In order to maintain SAP and thus be eligible for federal financial aid, a student must maintain minimum requirements for cumulative GPA (≥2.0 for undergraduates, ≥2.70 for master's students, and ≥3.0 for doctoral students). A student must also maintain minimum requirements for pace (credit earned for at least 67% of the credits attempted). In addition, the degree must be completed within the maximum time frame allowed for the program (defined as 150% of the required credits). Students who are not maintaining SAP will be notified by the McKelvey Registrar and, barring an approved appeal, are ineligible for aid for future semesters.

More information about Satisfactory Academic Progress (https://sfs.wustl.edu/resources/Pages/Satisfactory-Academic-Progress.aspx) is available from Student Financial Services.

Dissertation Dissenting Votes

In the rare case that there are faculty concerns that cannot be resolved through subsequent revisions and which therefore result in dissenting (negative) votes, the Committee Chair will refer the case to the Vice Dean of Research and Graduate Education. In the case of a single dissenting vote, the Committee Chair and the dissenting voter will be asked to explain the reasons for the dissent in a letter to the Vice Dean of Research and Graduate Education. After consulting with these and other members of the Committee, the Vice Dean may then decide to accept the majority opinion and approve the dissertation, or they may seek the opinion of an additional reader. After considering this additional evidence, the Vice Dean may either approve or decline to approve the dissertation. In the case of two or more dissenting votes, the Committee Chair and the dissenting voters will again be asked to explain the reasons for the dissent. The Vice Dean may then decide to decline to approve the dissertation, or they may ask the department or graduate program to name a Resolution Committee — consisting of three tenured or tenure-track professors at Washington University or elsewhere who did not serve on the original committee — to reexamine the dissertation and the candidate. A unanimous positive recommendation from this committee will be required in order for the Vice Dean to approve the dissertation. Failure of a department or graduate program to identify three faculty members to serve on this Resolution Committee will be tantamount to a rejection of the dissertation.

Advisor–Advisee Relationship

The relationship between an advisor and an advisee is critical to the success of a student in a PhD program. If a situation arises in which it is determined that the existing advisor–advisee relationship should be terminated, either by the advisor or the advisee, the student will enter into a 3-month probationary period so that the student can identify a new thesis research advisor. The student will continue to receive the customary stipend and allowances until an advisor for the thesis research is identified or for 3 months, whichever comes first. After the 3-month period, the student will either have established a new advisor–advisee relationship or will, at the discretion of the department, be provided a second 3-month probationary period. At the end of either probationary period, the student may be dismissed from the program as not having made the appropriate academic progress. A third probation will not be permitted. A student is able to appeal the probation decision following the appropriate procedures as outlined elsewhere in these policies.

Academic Records

The university will strive to protect, to the greatest extent possible, the confidentiality of students involved in matters of voluntary or involuntary leave. Because the university has an obligation to preserve the security of its community, the university cannot guarantee complete confidentiality where it would conflict with the university's obligation to investigate meaningfully matters that may threaten a student's health or safety or the safety and security of the university community. When some disclosure of the university's information or sources is necessary, that disclosure will be limited to the extent possible. Medical records of a student will be protected in accordance with the Washington University Habif Health & Wellness Center Notice of Privacy Practices. The university will, to the extent permitted by law, keep confidential all records of committee reviews. The records maintained by the Case Conference Committee will be available only to the administrator and other university officials in accordance with FERPA. All records will be destroyed after a period of 10 years from the date of final decision on involuntary leave or the student's decision to take voluntary leave or 10 years from the date of graduation or last semester of enrollment.

Disability Resources

Services for students with hearing, temporary or permanent visual, orthopedic, learning or other disabilities are coordinated through Disability Resources. Identifying oneself as having a disability is voluntary.

To the greatest extent possible, students with disabilities are integrated as equal members of the total student population. Services provided for students with disabilities may include but are not limited to readers, note takers, special parking, tutoring, counseling, appropriate academic accommodations (e.g., alternate testing conditions), and referral to community resources. To receive accommodations or services, students must initiate a request for services and are encouraged to contact Disability Resources upon admission or once diagnosed. For more information, please visit the Disability Resources website (https://students.wustl.edu/disability-resources/).

Academic Integrity

All students in the McKelvey School of Engineering are expected to conform to high standards of conduct. Students should refer to the Office of the Provost (https://provost.wustl.edu/vpge/) for the full text of the Academic and Professional Integrity Policy for PhD Students.

Academic Calendar

In addition to the university's academic calendar, McKelvey maintains an Engineering Academic Calendar (https://engineering.wustl.edu/academics/academic-calendar.html) with dates and deadlines that are specific to McKelvey students. This calendar includes course information, which is also helpful for non-McKelvey students taking engineering courses.

Doctoral Program Financial Information

Tuition Policy

The 2023-24 tuition and fees (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/tuition-financial-assistance.aspx) for graduate students in the McKelvey School of Engineering can be found on the McKelvey Graduate Admissions webpage. Tuition for full-time students is determined by each student's prime division, not by the division that teaches the course. Students should check with their department before enrolling in courses outside their division.

Tuition and Fees

The maximum tuition fee is the equivalent of 9 semester units. Students who enroll for 9 or more units per semester are automatically regarded as full-time students and are charged a flat full-time rate. Students enrolled for fewer than 9 units are charged on a per-unit basis. The tuition rate is subject to annual change.

Tuition Remission

McKelvey will provide tuition remission for the length of the student’s program as long as academic progress is being made. Students pursuing a certificate or an unrelated master's degree in addition to their PhD must consult the departments and advisors about credit sharing between the programs. To be eligible for tuition remission, courses must be offered at the graduate level. Depending on the program, graduate-level courses typically begin with courses numbered in the 500s. Students wishing to enroll in courses outside of these parameters or to take courses through the School of Continuing & Professional Studies and receive tuition remission will need to provide justification of relevancy to their program from their advisor. Students pursuing a certificate or an unrelated master's degree in addition to their PhD must consult their departments and advisors for approval. Tuition remission may not be provided for these courses. In the event that a PhD student is responsible for the tuition of a course, they should consult the school refund timeline and policies for information.

Financial Aid

PhD students interested in applying for federal student loans should complete the Free Application for Federal Student Aid (FAFSA) (https://studentaid.gov/h/apply-for-aid/fafsa/) for the appropriate academic year. For more information, contact mckelveygradfinancialaid@wustl.edu.

Insurance and Health-Related Subsidies

All full-time students on the Danforth Campus are charged a mandatory health fee that gives them access to Habif Health and Wellness Center. In addition, they are enrolled in the student health insurance plan, or they may present proof of comparable coverage to opt out. International students are not allowed to waive health insurance. Both the health fee and the health insurance premium are subject to annual change. Effective as of August 1, 2023, McKelvey covers the cost of the health fee as well as the health insurance and 90% of the optional dental insurance. Students are then responsible for paying the balance for the cost of these items as they appear on the student's bill. Students receiving special fellowship support may have different arrangements for covering their health fees and insurance. Please consult the program information for specific questions.

Part-Time Employment

If a full-time supported graduate student wishes to accept part-time employment within Washington University or outside of the university, the following guidelines must be followed. The Internal Revenue Service, the Washington University Human Resources Office, and U.S. Citizenship and Immigration Services all make important distinctions between students and employees. **These guidelines are designed to assist graduate students in retaining their status as students.**

McKelvey students receiving support are allowed a maximum of 6 hours per week of additional part-time employment while maintaining their status as students. Students **must** consult and receive approval from their programs in order to accept an additional position, as not all programs allow employment outside of the program.

Part-time employment as noted in this policy is separate from the request for Curricular Practical Training (CPT) and/or internships. International students should consult with the Office for International Students and Scholars regarding requirements for CPT, and all students should consult with their program regarding taking an internship position. Students taking an internship/CPT may have a reduction in or even cease receipt of their financial support from the program.

Master's Program Information

Master of Engineering Versus Master of Science Degrees

Master of Engineering (MEng) degrees are typically viewed as terminal degrees allowing maximum flexibility in course selection. Master of Science (MS) degrees are more structured in terms of required course work, and students with undergraduate degrees specifically in engineering are often better prepared to enter these master's programs. Graduates from MS programs are better prepared to move forward to doctoral programs, as they often become more involved in research experience. However, MS programs also include course-only options for those not interested in doing research.

There are different ways to earn a master's degree at Washington University:

- There are a number of Engineering disciplines that admit students who wish to pursue a terminal master's degree. In some programs, both the course option and thesis option are available.
- Undergraduate students at Washington University may apply for the Bachelor's/Master's program in Engineering, in which graduation with a BS or AB is followed by one year of graduate study leading to the MEng or MS degree. This option is described in the Combined Majors and/or Multiple Degrees (http://bulletin.wustl.edu/undergrad/engineering/#combinedmajors) section of the *Undergraduate Bulletin*.
- Students who have not previously earned a master's degree in the same field as their PhD may earn the MS on the way to their PhD. This option is available in some disciplines but not in all of them.
- Students who have not previously earned a master's degree in the same field as their PhD may be awarded an MS for work done in a PhD program that they are leaving without completing. This option is available in some disciplines but not in all of them.

General Requirements

Candidates for master's degrees should note that, in most MS programs, both the thesis option and the course option are available. The course option may be of particular interest to part-time students who, because of their employment, might find it more convenient than the thesis requirement. All candidates for the master's degrees should consult with their advisor to determine the option they will follow.

All requirements for master's degrees must be completed within six years from the time the student is admitted to graduate standing. A maximum of 6 units of graduate credit obtained at institutions other than Washington University may be applied toward the master's degree awarded by Engineering. Transfer credit must be recommended and approved by the department chair or program director and advisor, as well as by the Engineering registrar. No courses carrying grades lower than B can be accepted for transfer credit.

For the thesis option, a minimum of 24 units of course work and a minimum of 6 units of research are required. The student must also write a satisfactory thesis prepared under the supervision of a member of the Engineering faculty. Candidates for master's degrees under the course option must submit a minimum of 30 units of approved graduate course credit. A department may have additional requirements beyond the minimum requirement stated previously. Students should consult with their advisor as several master's degrees require more than 30 graduate units.

Multiple Master's Degrees

To earn more than one master's degree from Engineering, the student's final program of course work for each such master's degree must include a minimum of 15 units of preapproved courses not included as part of the final program of course work for any other master's degree awarded by Engineering.

Master's Thesis

A candidate for the MS degree under the thesis option should prepare their thesis according to the Master's Thesis Format Guidelines (https://engineering.wustl.edu/offices-services/student-services/graduate-student-services/thesis-dissertation-submission.html) found on the Engineering website.

The candidate's department chair or program director will appoint a thesis committee of three faculty members, with the student's advisor as chair, who will read the thesis and judge its acceptability.

Master's Final Examinations

The final examination for the MS candidates under the thesis option consists of an oral examination conducted by the thesis committee and any additional faculty members that the department or program chairman may wish to designate. At this examination, the candidate will present and defend the thesis.

Candidates for the MS under the course option may be required to pass a final examination. The form of this examination is determined by the faculty of the area of specialization, and students should consult their advisors, department chairs, or program directors for details concerning this examination.

Administration

Dean's Office
314-935-6350

Department of Biomedical Engineering
314-935-6164

Department of Computer Science & Engineering
314-935-6160

Department of Electrical & Systems Engineering
314-935-5565

Department of Energy, Environmental & Chemical Engineering
314-935-6070

Department of Mechanical Engineering & Materials Science
314-935-6047

Engineering Information Technology
314-933-3333

Engineering Graduate Student Services
314-935-5830

Sever Institute
314-935-5484

Master's Program Policies

Admissions

Eligibility

Washington University encourages and gives full consideration to all applicants for admission and financial aid, without regard to race, color, age, religion, sex, sexual orientation, gender identity or expression, national origin, veteran status, disability or genetic information.

McKelvey School of Engineering is strongly interested in recruiting, enrolling, retaining and graduating students from diverse backgrounds. Applications for admission by students from diverse backgrounds to any of our degree programs are encouraged and welcomed. To the greatest extent possible, students with disabilities are integrated into the student population as equal members.

To be considered for admission into a graduate degree program, applicants must hold a bachelor's degree from an accredited institution prior to starting the graduate program. Most of the engineering degree programs require a previous degree in science, technology, engineering or mathematics.

Current engineering graduate students who wish to be admitted into another engineering graduate program must be admitted at least one semester prior to their anticipated graduation semester.

Application Process

Degree programs set their own application deadlines. Applicants should check deadlines (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/application-process.aspx) through the McKelvey School of Engineering. It is generally advantageous to the applicant to complete the application well in advance of the deadline.

The application (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/default.aspx) is available online through the School of Engineering website. Applications are ready for final consideration after the required items from the application checklist have been submitted.

Please review our application checklist (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html) for details on all materials needed for a complete application.

Admission and financial aid awards are for a specific academic year; students who do not matriculate that year must normally reapply. Admitted students can request a deferral of admission for up to one year from the admissions office. Applicants to whom admission is not offered may reapply for a future semester.

Admission of International Students

International students considering application to Washington University for graduate study should have a general familiarity with academic practices and university customs in the United States. All international students are required to present evidence of their ability to support themselves financially during graduate study. International students are required to submit valid English proficiency score reports from the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). Tests should be taken in time for results to reach Washington University by the application deadline. Official test scores are required at the time of application.

The English proficiency requirement may be waived during the application process. Please review our waiver eligibility criteria (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html) found on our application checklist (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html).

Students Not Candidate for Degree (SNCD)

SNCD admission may be granted to qualified students who hold a bachelor's degree or its equivalent, who wish to enroll in graduate courses on a non-degree basis, and who receive approval from a degree program. Examples include students in good standing at other graduate schools and students who wish to test their capabilities in a graduate setting. Students in this category may take a maximum of 9 units, and they may later apply to a degree program and transfer these units to meet degree requirements. SNCD students are not eligible for Title IV Federal Funding. Please contact Engineering Graduate Admissions (https://engineering.wustl.edu/academics/graduate-admissions/) for application requirements.

Attendance

Each professor in the McKelvey School of Engineering decides how many absences a student may have and still pass the course. Professors are expected to give reasonable consideration to unavoidable absences and to the feasibility of making up work that has been missed. Students are expected to explain to their professors the reasons for any absences and to discuss with them the possibility of making up missed assignments.

Units and Grades

Credit-conferring grades for graduate students are as follows: A, B, C, or D (these grades may be modified by a plus or minus); S, satisfactory or U, unsatisfactory (S and U are used for all research units and should be noted at the end of each semester).

Other grades are F, failing; N, not submitted yet; X, final examination missed; and I, incomplete. The mark of I reverts to an F grade at the close of the next full semester a student is in residence.

McKelvey uses a 4-point scale for calculating grade-point averages, with A+/A = 4, B = 3, C = 2 and D = 1. A plus (other than with an A grade) adds 0.3 to the value of a grade, whereas a minus subtracts 0.3 from the value of the grade.

Auditing a Course

A student may register for some courses as an auditor. The criteria for a successful audit are determined by the course instructor, and the student should work with the instructor to ensure that these criteria are understood. Generally speaking, the completion of homework and the taking of exams are not required. The grade L signifies a successful audit, and the grade Z signifies an unsuccessful audit. Neither grade affects a student's grade-point average, and the course's units do not contribute to the student's total cumulative degree-seeking units. Audit courses do not count toward any degree, nor do they count toward full-time status determination. They do count toward the 21-unit cap per semester, and audit units are charged at the standard full-time or part-time per-unit rate. Class attendance is normally required to earn a grade of L; unsatisfactory attendance will result in a grade of Z.

Incomplete Grades

The grade I (incomplete) indicates that the work of a student has been generally acceptable but that extenuating circumstances led to certain requirements not having been met. The grade of X is recorded when a student is absent from a midterm or final examination because of illness or other unavoidable reason, provided the work has been otherwise satisfactory.

Grades of X and I must be removed no later than the close of the next full semester a student is in residence. On failure to make up an X or I grade, the student will not receive credit for the course, and the grade will be changed to F unless the student has been explicitly excused by the associate dean.

A student should **not** re-enroll in a course to complete an I grade. Enrolling in the course a second time invokes the Course Retake Policy (https://bulletin.wustl.edu/undergrad/engineering/policies/#repeating).

Course Retake Policy

McKelvey graduate students may choose to retake a course with the permission of their advisor. If a course is repeated, only the second grade is included in the calculation of the GPA. Both enrollments and grades are shown on the student's official transcript. The symbol R next to the first enrollment's grade indicates that the course was later retaken. Credit toward the degree is allowed for the latest enrollment only. The R option may be invoked only once per course, and the original grade option must be retained.

Student Grievance

From time to time, students may feel that they have legitimate complaints regarding academic matters or an interaction with a faculty member. It is important that students and faculty have a common understanding of how such complaints may be expressed and resolved. Students with complaints regarding academic matters should initially seek resolution from their faculty advisor, then from their director of graduate studies, and finally from the chair of their degree program. Complaints that remain unresolved may be addressed to the Associate Dean of Graduate Student Services. The final court of appeal for all doctoral students in the school is the Vice Dean of Research and Graduate Education. Washington University policies state that members of the university community can expect to be free from discrimination and harassment. Students, faculty, staff and outside organizations working on campus are required to abide by specific policies prohibiting harassment. An allegation of discrimination or harassment may be appealed to the Vice Chancellor for Human Resources, who will determine whether to convene the Title IX Grievance Committee to hear the case.

Additional Course Information for Graduate Students

To count toward a graduate degree, courses must be offered at the graduate level, taken for a grade, and approved in advance by the student's advisor and program as eligible to count toward the student's degree. Depending on the program, graduate-level work begins with courses numbered at the 400 or 500 level. Audited courses and courses taken on a pass/fail basis cannot be counted toward the degree. Students should consult their advisors regarding these options.

Communication Tools Course for International Students

International students who were required to submit valid English proficiency scores for application and do not meet the waiver eligibility criteria (https://engineering.wustl.edu/academics/graduate-admissions/application-checklist.html), will be required to take an Engineering Communication Tools course during their first semester. This course does not count toward degree requirements and does not require any additional tuition; it is graded on a pass/fail basis, so it is not factored into the grade-point average.

Transfer Credit

A maximum of 6 units of graduate credit obtained at institutions other than Washington University may be applied toward the master's degree. Approved transfer credit for undergraduate course work completed at a different institution cannot be posted until a letter is received from that institution's registrar, which states the graduate-level course work was not used to satisfy undergraduate degree requirements.

Transfer credit must be recommended by the advisor, department or program chair and approved by the appropriate registrar. No graduate courses carrying grades lower than B can be accepted for transfer toward any graduate degree.

No courses will be accepted toward degree requirements if the course exceeds the 10-year maximum time period, unless those courses have the formal approval of the McKelvey Master Committee.

Student Status

All graduate students in Engineering must register each fall and spring semester until all degree requirements are complete. All registrations require online approval by the student's faculty advisor. Students should register in one of the below three categories.

Graduate students who do not register in one of the below categories may have to apply for reinstatement if they wish to re-enroll at a future time. Students should contact Graduate Student Services at 314-935-5830. Students seeking reinstatement may be required to pay a reinstatement fee, take special reinstatement examinations, and repeat previous work if their previous work fails to meet contemporary standards.

Active Status

A graduate student is viewed as having an active full-time status if enrolled in 9 or more units or an active part-time status if enrolled in fewer than 9 units. Graduate students must be authorized by their advisor prior to registration. International master's students on F1 and J1 visas are required to take a minimum of 9 units per semester except during their final semester. In order to have part-time status during their final semester, international master's students must complete a Reduced Course Load form, which is available from the Office of International Students and Scholars (OISS).

Continuing Student Status

The Continuing Student Status course option may be used when graduate students are approved to register for fewer than 9 units but still need to maintain their full-time status. When students are registered for the Master's Continuing Student Status (883) course, they will still be viewed as having a full-time status, even if they are taking fewer than 9 units. Placeholder courses are 0-unit audit courses with no tuition charges associated with them for engineering students; however, students may be charged health insurance and/or student activity fees associated with full-time status. The EGS 883 course option is contingent upon advisor and departmental approval. **Note:** The 883 status is not available for master's students on F1 and J1 visas; domestic master's students may register under the 883 status only during their final semester and with departmental approval.

Nonresident or Inactive Status

Graduate students who do not need to maintain full-time status and who do not need to register for any course or research units during a given semester should, with departmental and advisor approval, register under the Nonresident/Inactive Status placeholder course option. Graduate students on an official leave of absence should also register under this status but, again, only with advisor and departmental approval. A master's student should register for this status using the EGS 885 course number. Placeholder courses are 0-unit audit courses with no tuition charges associated with them for engineering students. Students registered this way are not viewed as full-time students and will not automatically have university health insurance fees or coverage. This registration does not defer student loans, and it does not serve as a legal status for international students. The nonresident/inactive status will ensure that the student's major program will remain open. This option is not available to international students (due to F1 and J1 visa requirements), unless approved by the OISS. A nonresident/inactive status is allowed only for a few semesters, at the department's discretion. Any student contemplating a nonresident/inactive status must be aware of the residency requirements and the total time limitation required for degree completion.

Academic Probation and Suspension

The following are the minimal standards to remain in good academic standing as a Master's student. Degree programs may set stricter standards, but they may not relax those listed below. Acceptability of grades below B- for the fulfillment of degree requirements is determined by individual departments.

- A Master’s student is eligible for academic probation if a semester or cumulative GPA drops below 2.70.
- A Master's student is eligible for academic suspension if any one of the following occurs:
    - The student earns a semester or cumulative GPA less than 2.00, or
    - The student has been on probation for two semesters and has not attained a 2.70 cumulative GPA.

Academic probation represents a warning that things are not going well academically. Students placed on academic probation may continue to stay enrolled in their degree programs but must meet with the Director of Graduate Student Affairs. This meeting will serve as an opportunity for the student to identify areas for improvement and to create a strategy for success for the duration of their degree program.

Special academic probation represents a decision by the department to allow a student otherwise eligible for suspension to continue their studies under a special probationary status. Being placed on special probation may include additional student limitations, such as limit on enrolled units. If a student is given special probation in lieu of suspension, the conditions of the probation cannot be appealed.

Academic suspension represents being dismissed from the program. Students placed on academic suspension are not eligible to enroll or to continue their degree programs. There is no guarantee that students who have been suspended will be allowed to return.

- Students who are suspended may appeal to the McKelvey Master Committee. Appeals should be sent to the registrar in the McKelvey School of Engineering who will then forward the appeal statement for review. If a student decides not to appeal an academic suspension or if a student's appeal is not successful, registration for the upcoming semester will be cancelled, and the student's academic record will be closed.
- Students who have been suspended may apply for reinstatement after one year has passed. Reinstatement requests should be sent to the registrar in the McKelvey School of Engineering who will forward the requests to the program director. Students requesting reinstatement will need to show that they have successfully completed challenging full-time course work at a different institution (generally, for at least one year), that they have been employed in a full-time position (generally, for at least one year), or a combination of the two (school and work). Reinstatement back into the program will be decided by the program director and/or the program department. Students may be asked to re-apply to the program through the full application process.

Satisfactory Academic Progress for Title IV Financial Aid

Federal regulations require that students receiving federal Title IV financial aid maintain Satisfactory Academic Progress (SAP). The minimum GPA requirements needed to maintain eligibility for SAP are dictated by the specific program of study. In each case, per the requirements of 34 C.F.R. 668.34(a)(4(ii), the federal student aid program requires a minimum of a C average to maintain eligibility for aid, but an individual degree or certificate program may have a higher minimum GPA for federal SAP.

SAP is evaluated annually at the end of the spring semester. In order to maintain SAP and thus be eligible for federal financial aid, a student must maintain minimum requirements for cumulative GPA (≥2.0 for undergraduates, ≥2.70 for master's students, and ≥3.0 for doctoral students). A student must also maintain minimum requirements for pace (credit earned for at least 67% of the credits attempted). In addition, the degree must be completed within the maximum time frame allowed for the program (defined as 150% of the required credits). Students who are not maintaining SAP will be notified by the McKelvey Registrar and, barring an approved appeal, are ineligible for aid for future semesters.

More information about Satisfactory Academic Progress (https://sfs.wustl.edu/resources/Pages/Satisfactory-Academic-Progress.aspx) is available from Student Financial Services.

Disability Resources

Services for students with hearing, temporary or permanent visual, orthopedic, learning or other disabilities are coordinated through Disability Resources. Identifying oneself as having a disability is voluntary.

To the greatest extent possible, students with disabilities are integrated as equal members of the total student population. Services provided for students with disabilities may include but are not limited to readers, note takers, special parking, tutoring, counseling, appropriate academic accommodations (e.g., alternate testing conditions), and referral to community resources. To receive accommodations or services, students must initiate a request for services and are encouraged to contact Disability Resources upon admission or once diagnosed. For more information, please visit the Disability Resources website (https://students.wustl.edu/disability-resources/).

Leaves of Absence

Engineering students may petition to take a leave of absence. On a leave of absence, students in good standing are assured re-enrollment within the next year. Before returning, the student is to notify the McKelvey School of Engineering and submit a reinstatement form at least six weeks prior to the beginning of the appropriate term. A student wishing to take a medical leave of absence must have a recommendation for the medical leave of absence from Habif Health and Wellness Center (http://shs.wustl.edu/) submitted to the appropriate dean in the McKelvey School of Engineering prior to leaving and prior to re-enrollment. The dean will decide whether or not to grant the request for the medical leave of absence and re-enrollment upon reviewing the recommendations from Habif Health and Wellness Center and the student's file.

Academic Integrity

All students in the McKelvey School of Engineering are expected to conform to high standards of conduct. Our statement on student academic integrity is intended to provide guidelines on academic behaviors that are not acceptable. Visit the McKelvey Academic Integrity (https://engineering.wustl.edu/current-students/student-services/Pages/academic-integrity-policy.aspx) webpage to review the policy and learn more about our process.

Academic Calendar

In addition to the university's academic calendar, McKelvey maintains an Engineering Academic Calendar (https://engineering.wustl.edu/academics/academic-calendar.html) with dates and deadlines that are specific to McKelvey students. This calendar includes course information, which is also helpful for non-McKelvey students taking engineering courses.

Master's Program Financial Information

Tuition Policy

The 2023-24 tuition and fees (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/tuition-financial-assistance.aspx) for graduate students in the McKelvey School of Engineering can be found on the Engineering graduate admissions webpage. Tuition for full-time students is determined by each student's prime division, not by the division that teaches the course. Students should check with their department before enrolling in courses outside their division.

Students who will receive reimbursement from their employers are responsible for tuition being paid by the due date. Employer reimbursements that are contingent upon course completion and/or a satisfactory grade will not exempt the student from stated due dates and the assessment of penalties.

All **full-time** graduate students in Engineering (DSc and master's) are assessed tuition at a full-time tuition rate. **Part-time** graduate students are assessed tuition on a per-unit basis. If a full-time student withdraws from courses to become a part-time student after the add/drop (100%) period, tuition is recalculated to the part-time per-unit rate for the remaining units, and the refund schedule below is applied to the tuition of the withdrawn courses. Part-time students should also follow the refund schedule below. Refunds are computed from the date on which the course is dropped, as reflected in the Student Information System. Refund checks are made available as soon as possible (usually four to six weeks after the drop is completed).

Period of Withdrawal	Percent of Refund
1st or 2nd week of classes	100%
3rd or 4th week of classes	80%
5th or 6th week of classes	60%
7th or 8th week of classes	50%
9th or 10th week of classes	40%
After 10th week of classes	No refund

Note: After the date of the first class meeting, refunds are not granted for **short courses,** which run less than the full semester length. Questions concerning the refund policy should be directed to the Engineering Accounting Office at 314-935-6183.

Financial Aid

Master's students are expected to be self-supporting and are generally not eligible for any institutional financial assistance. However, participants in the bachelor's/master's program (https://engineering.wustl.edu/prospective-students/graduate-admissions/Pages/bs-ms.aspx) and the dual degree program (https://engineering.wustl.edu/prospective-students/dual-degree/Pages/masters-degree-programs.aspx) could qualify for tuition remission. All master's students who attend at least half-time (i.e., 3 units in the summer and 4.5 units in the fall and spring) and who are U.S. citizens or permanent residents may be eligible for federal student loans.

Students should complete the Free Application for Federal Student Aid (FAFSA) (https://studentaid.gov/h/apply-for-aid/fafsa/) for the appropriate academic year. For more information, contact mckelveygradfinancialaid@wustl.edu.

Loans

The federal government provides a number of student loan programs, and there are rules and requirements for each program. These programs are subject to change by the government agencies that oversee them, and they require that detailed financial information be provided by the student. For more information about federal loans (https://studentaid.gov/) available to graduate students, please visit the Engineering website (https://engineering.wustl.edu/academics/graduate-admissions/tuition-financial-assistance/financial-assistance.html).

Interdisciplinary Opportunities

Washington University offers courses through interdisciplinary programs that include studies in a variety of disciplines that cross traditional academic boundaries and support academic areas outside of the schools.

- A limited opportunity for some Washington University students to enroll in courses at Saint Louis University and the University of Missouri-St. Louis is available through the Inter-University Exchange Program (p. 135).
- The Skandalaris Center (p. 136) offers cocurricular programming and practical, hands-on training and funding opportunities to students and faculty in all disciplines and schools.

Inter-University Exchange Program

The Inter-University Exchange (IE) program between Washington University, Saint Louis University (SLU), and the University of Missouri–St. Louis (UMSL) began in 1976 as an exchange agreement encouraging greater inter-institutional cooperation at the graduate level. Over time, this program has evolved to include undergraduate education. The basic provisions of the original agreement are still in place today, and participation continues to be at the discretion of each academic department or unit.

At Washington University, there are several schools that **do not participate** in this program (i.e., degree-seeking students in these schools are not eligible to participate in the IE program, and courses offered in these schools are not open to SLU and UMSL students attending Washington University through the IE program). They are the School of Law, the School of Medicine, the McKelvey School of Engineering, and the School of Continuing & Professional Studies. The Washington University schools that are open to participation in the IE program may have specific limitations or requirements for participation; details are available in those offices.

The following provisions apply to all course work taken by Washington University students attending SLU or UMSL through the IE program:

- Such courses can be used for the fulfillment of degree or major requirements. (Students should consult with their dean's office for information about how IE course work will count toward their grade-point average, units and major requirements.)
- Such courses are not regularly offered at Washington University.
- Registration for such courses requires preliminary approval of the student's major/department advisor, the student's division office or dean, and the academic department of the host university.
- Students at the host institution have first claim on course enrollment (i.e., a desired course at SLU or UMSL may be fully subscribed and unable to accept Washington University students).
- Academic credit earned in such courses will be considered as resident credit, not transfer credit.
- Tuition for such courses will be paid to Washington University at the prevailing Washington University rates; there is no additional tuition cost to the student who enrolls in IE course work on another campus. However, students are responsible for any and all fees charged by the host school.
- Library privileges attendant on enrolling in a course on a host campus will be made available in the manner prescribed by the host campus.

Instructions

Washington University students must be enrolled full-time to participate in the IE program and have no holds, financial or otherwise, on their academic record at Washington University or at the host institution.

1. The student must complete the IE program application form. Forms are available from the Office of the University Registrar website (https://registrar.wustl.edu/student-records/registration/the-inter-university-exchange-program/).
2. The student must provide all information requested in the top portion of the form and indicate the course in which they wish to enroll.
3. The student must obtain the approval signature of the professor teaching the class or the department chair at SLU or UMSL, preferably in person.
4. The student also must obtain the approval signatures of their major advisor at Washington University and the appropriate individual in their dean's office.
5. Completed forms must be submitted to the Office of the University Registrar in the Women's Building a minimum of one week before the start of the term.

Course enrollment is handled administratively by the registrars of the home and host institutions. Washington University students registered for IE course work will see these courses on their class schedule and academic record at WebSTAC under departments I97 (SLU) and I98 (UMSL). Final grades are recorded when received from the host institution. The student does not need to obtain an official transcript from SLU or UMSL to receive academic credit for IE course work at Washington University.

Contact:	Office of the University Registrar
Phone:	314-935-5959
Email:	registrar@wustl.edu
Website:	http://registrar.wustl.edu/student-records/registration/the-inter-university-exchange-program

Skandalaris Center for Interdisciplinary Innovation and Entrepreneurship

The Skandalaris Center for Interdisciplinary Innovation and Entrepreneurship (https://skandalaris.wustl.edu) is the hub of creativity, innovation, and entrepreneurship at Washington University. We believe everyone can be entrepreneurial. Skandalaris provides programming where anyone can explore their creative and entrepreneurial interests, develop an entrepreneurial mindset, and go from ideation to launch.

Mission

The Skandalaris Center fosters and empowers an inclusive community that finds opportunities in problems and transforms ideas into action. We build an ecosystem of education, research, and resources that engages all WashU students, faculty, alumni, and staff as entrepreneurial leaders and collaborators.

Who We Serve

We work with the best and brightest at WashU — the change-makers, thought leaders, and visionaries — to solve the world's problems and meet local needs through innovation and entrepreneurship. As an interdisciplinary center, our initiatives serve students, faculty, staff, and alumni from all levels and disciplines.

Our Initiatives

We develop programs for WashU entrepreneurs, creatives, innovators, and scholars. Our commitment to interdisciplinary innovation and entrepreneurship is motivated by the following beliefs:

- *Everyone can be creative.* We provide hands-on experiences and the creative means to solve problems.
- *Innovation is the backbone of entrepreneurship.* Our opportunities are designed to develop and share new ideas while connecting with other WashU entrepreneurs and innovators.
- *Good ideas are one opportunity away from success.* Our programs are created to help WashU entrepreneurs and innovators access the resources they need to take their ideas to the next level.
- *Knowledge and skills are key to innovation and entrepreneurship.* Our Center offers events and opportunities to help our community of WashU entrepreneurs, creatives, and innovators learn the ins and outs of innovation and entrepreneurship.

Programs and Resources

- **Experts on Call (https://skandalaris.wustl.edu/resources/experts-on-call/)**
  This program provides an opportunity for the WashU community to connect with experts in the Skandalaris Center or remotely, free of charge.
- **Honors in Innovation & Entrepreneurship (https://skandalaris.wustl.edu/sc-programs/honors-in-innovation-and-entrepreneurship/)**
  Students who have shown exemplary involvement in innovation and entrepreneurship during their time at Washington University are recognized through this program. Honors are earned by accumulating points through a combination of curricular and cocurricular activities.
- **In-Residence Program**
  This program provides WashU students, faculty, staff, and alumni with the opportunity to learn from and work with professionals with extensive industry experience.
- **PhD Citation in Entrepreneurship (https://skandalaris.wustl.edu/sc-programs/entrepreneurship-citation/)**
  This program provides opportunities for PhD students who are interested in developing skills and experiences in the areas of entrepreneurship and innovation.
- **Pivot 314 Fellowship**
  The Pivot 314 Fellowship is a year-long program presented by the Office of the Provost and the Skandalaris Center for Interdisciplinary Innovation and Entrepreneurship. Pivot 314 offers graduate students curated programming focused on professional development and on strengthening leadership and communications skills, as well as internship opportunities.
- **Resources (https://skandalaris.wustl.edu/resources/)**
  The Skandalaris Center, Washington University, and external services and resources are available to support innovators and entrepreneurs.
- **Skandalaris Spaces**
  Our collaboration space is available for hosting meetings or events. Requests should be made a week in advance.
- **Skandalaris Startup Webinars, Panel Discussions, and Workshops**
  These webinars provide an exciting way for alumni to reconnect and share their experiences with entrepreneurship. We also offer free, noncredit workshops designed to encourage creativity, innovation, and entrepreneurship.
- **Startup Venture Promotion**
  The Skandalaris Center is happy to help Washington University in St. Louis students, faculty, staff, and alumni with promoting their startup ventures.
- **Student Entrepreneurial Program (StEP) (https://skandalaris.wustl.edu/sc-programs/step/)**

StEP provides a unique opportunity for students to own and operate a business on campus that serves the WashU community. Student owners can supplement the valuable business and entrepreneurial skills they learn in the classroom while gaining real-world experience as they manage and lead their own businesses.

- **Student Groups (https://skandalaris.wustl.edu/sc-programs/student-groups/)**
  There are many organizations that allow students to gain experience and make valuable interdisciplinary connections in the areas of creativity, innovation, and entrepreneurship.
- **Venture Development**
  The WashU community is invited to set an appointment with a member of our team for help with ideas and businesses at any stage. We will work with these individuals to brainstorm ideas, strengthen financial models, draft business plans, perfect pitches, and more.
- **Washington University Entrepreneurship Courses (https://skandalaris.wustl.edu/sc-programs/entrepreneurship-courses/)**
  Courses in entrepreneurship offered across the university are available to students at all levels and in all disciplines.

Competitions

- **IdeaBounce (https://skandalaris.wustl.edu/sc-programs/ideabounce/)®**
  IdeaBounce® is both an online platform and an event for sharing venture ideas and making connections. This is an opportunity for participants to pitch their ideas (no matter how "fresh"), get feedback on them, and make connections. In-person events happen frequently throughout the fall and spring semesters.
- **Skandalaris Venture Competition (SVC) (https://skandalaris.wustl.edu/sc-programs/svc/)**
  The SVC provides expert mentorship to new ventures and startups to ready them for commercializing their ideas, launching, and pitching to investors. Teams will develop materials focused on explaining the ideas that they are working on to a broad audience.
  - **Who Can Apply:** Current Washington University students and alumni (within one year of graduation) with an early-stage venture or idea
  - **Award:** Up to $22,500
- **Global Impact Award (GIA) (https://skandalaris.wustl.edu/sc-programs/global-impact-award/)**
  The GIA awards WashU–affiliated ventures with inventions, products, ideas, and business models that will have a broad and lasting impact on society.
  - **Who Can Apply:** WashU students, postdocs, residents, and alumni who have graduated within the last 10 years
  - **Award:** Up to $50,000

Learn More

Please contact the Skandalaris Center (https://skandalaris.wustl.edu/get-connected/) to sign up for our newsletter and for additional information about all programs.

Phone:	314-935-9134
Email:	sc@wustl.edu
Website:	http://skandalaris.wustl.edu

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