Engineering and Science Electives

Department of Biomedical Engineering
University of Minnesota

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Philosophy

Biomedical engineering (BME) encompasses a broad range of approaches to improving health through technology. To function as a biomedical engineer, it is important to go beyond a broad training in the core principles of BME to also gain a depth of expertise in one specialized area of BME. To ensure that students gain depth in one particular area, the department requires that 27 credits of advanced engineering and science coursework be completed beyond that in the core curriculum. These advanced courses should have a coherent theme and should meet the requirements specified in the "policy" section below.

Because BME is a rapidly evolving field, it is important that the areas of emphasis *not be rigidly codified*, but rather that students be allowed to ***customize*** their advanced studies to suit their own particular interests. Nevertheless, the department recognizes that established areas of BME are of interest to many students and that students generally seek advice as to which courses would both meet the students' needs and satisfy the department's requirements. To assist students with the process of course selection, the department has developed the following lists of possible courses for some of the more established areas of BME. However, it is important to emphasize that students are *not required to select one of these areas*, *nor are they required to use only those courses listed*.

Procedure

Students should review the course descriptions and select an appropriate set of courses consistent with the requirements. The courses selected should be entered on the form "Biomedical Engineering/Science Elective Planning Worksheet" and then a meeting scheduled with the appropriate Emphasis Area Advisor (EAA). If the planned Emphasis Area is not specified below, then the Director of Undergraduate Studies (DUS) will serve provisionally as the EAA, until the appropriate EAA is identified. The DUS will also assist in identification of alternative areas of emphasis. The plan should be discussed with and approved by the EAA, before it is submitted to the DUS for departmental approval. Department approval of the plan is required for graduation. Changes to the plan must be approved by the EAA and DUS. This guide will be updated regularly on the web and the most recent version should be obtained by the student prior to registration.

Policy

It is necessary that the engineering and science elective courses be *technically coherent* and that the courses be mainly in engineering and at an advanced level. In terms of specific requirements:

1) A specific emphasis area must be declared.
2) A maximum of 10 credits of pure science may be counted toward the total. The remainder *(at least 17 credits) must be in engineering or in technical courses (i.e. courses offered through science and medical departments/programs) having significant engineering content, as determined by the EAA in consultation with the DUS using the definition of "engineering credits" given below.
3) A maximum of 3 credits of 1000- and 2000-level courses may be counted toward the total.
4) A minimum of 19 credits at the 4000-level or higher.
5) A maximum of 6 credits of research (under a "Directed Research" course listing or similar course title) may be counted toward the total.

Definition of "Engineering Credits"

The definition of *engineering credits* is: 1) Any course offered by an engineering program, or 2) Any course (or course component) that teaches students how to practically apply the knowledge of pure sciences. Students' must consult the DUS about the number of engineering credits allowed for such courses.

Using the course lists

The course lists below are meant to serve as guides to students. The prerequisites are either directly taken from the 2009-2010 catalog, or in the case of BME courses, represent suitable equivalents to the published prerequisites as determined by the BME Department in consultation with the department offering the course (see below).

Prerequisite equivalencies: Using BMEn courses as prerequisites for non-BMEn courses

Upon satisfactory completion of the appropriate BMEn 3000-level course(s) listed below, students should be adequately prepared to register for non-BMEn courses that have the equivalent course as a prerequisite. The equivalency does not imply that credit has been earned for the equivalent course, only that the BMEn course(s) can serve as an acceptable prerequisite for advanced coursework in a given area.

AEM

BMEn 3001 = AEM 2011, AEM 2012
BMEn 3101 = AEM 4201
No ESE credit allowed for: AEM 2011, AEM 2012, AEM 4201

ChEn

BMEn 3101 = ChEn 4005 + ChEn Upper Division
BMEn 3001 + BMEn 3101 = ChEn 4201
BMEn 3401 = ChEn 4601
No ESE credit allowed for: ChEn 4005, ChEn 4201, ChEn 4601

EE

BMEn 3201 = EE 2011
BMEn 3401 = EE 3015
No ESE credit allowed for: EE 2001, EE 2002, EE 2011, EE 3015

ME

BMEn 3001 + BMEn 3101 = ME Upper Division
BMEn 3101 + BMEn 2401 = ME 3331
BMEn 3101 = ME 3332
BMEn 3401 = ME 3281
No ESE credit allowed for: ME 3281, ME 3331, ME 3332

MatS

BMEn 3301 = MatS 3011
No ESE credit allowed for: MatS 3011

Pre-Med Advice

The UMN Medical School is changing its requirements for students applying to enter in 2009 and beyond. These are posted at http://www.meded.umn.edu/admissions/prerequisites_2009.php.

The required courses are as follows (with corresponding B.Bm.E. course requirements that will satisfy them shown parenthetically):

* Biology with lab (BMEn 2501)
* Chemistry with lab (Chem 1021)
* 4 courses in life sciences (including physics) at least 2 of which are at the 3000-level or higher (Phys 1301, Phys 1302, Chem 2301, Phsl 3063 and/or the "Medical School recommended courses" in Biochem and Genetics taken towards the Cell/Tissue Engineering Emphasis Area (CTE EA) - this is the EA that most directly allows the Medical School required and recommended courses to be satisfied)
* 1 writing intensive course ("W") at the 3000-level or higher in the humanities or social sciences (Lib Ed course)

The recommended courses are as follows (with corresponding B.Bm.E. course requirements that will satisfy them shown parenthetically):

Biochemistry (CTE EA elective)
Genetics (CTE EA elective)
Statistics (Stat 3021)
Psychology (Lib Ed course*)
Ethics (Lib Ed course*)
Independent learning course (CTE EA elective: Directed Research BMEn 4710)
Seminar-type course with small group discourse (Lib Ed course*)
Foreign Language (Lib Ed course*)

*Lib Ed courses taken to satisfy the B.Bm.E. requirements are assumed to satisfy the CLE requirements

Be aware that while the UMN Medical School has dropped OChem II and OChem Lab as required/recommended courses, many other medical schools currently require one or both of these courses and the MCAT tests material covered in OChem II. For example, ~3/4 of all programs currently require OChem Lab according to the Health Careers Center. Note that if you take these courses (OChem II = CHEM 2302, OChem Lab = CHEM 2311), they can be accommodated in the CTE EA.

The "Medical School Admission Requirements (MSAR) 2010-2011" lists the admissions requirements for all (~125) medical school programs. You can borrow it from the Health Careers Center (2-565 Moos Tower) or purchase it for $25 via the link below. You could then know what the requirements are for the programs you envision applying to.
https://services.aamc.org/Publications/index.cfm?fuseaction=Product.displayForm&prd_id=186&prv_id=226

Note that courses which have been granted AP credit will no longer be accepted as fulfilling the course requirements (i.e. for applicants for 2009 matriculation) - you must take another course in the subject area and it is highly recommended that you take a different (higher level) course in the same subject area.

Anyone planning to apply to Medical School is strongly encouraged to take the upcoming "Preparing for Medical School" workshops offered through the Health Careers Center (2-565 Moos Tower). The direct link for information and registration is http://www.healthcareers.umn.edu/hcc/events/home.html. There are other workshops described at the site that may also be of interest.

Note that it is to your advantage to apply as early possible in the June 1 - Nov 15 cycle. Also, it is essential that you plan ahead to accumulate the appropriate exposures to and experiences in the medical field. The Health Careers Center workshops provide much advice in this regard.

If you are within one year of applying to Medical School but have not yet submitted your medical school application via AMCAS, you may arrange a meeting in the UMN Medical School Admissions Office if you have specific questions about applying to UMN's Medical School not covered in the Health Careers Center sessions. Please contact meded@umn.edu or 612/625-7977 to schedule an appointment.

Biomechanics

Emphasis Area Advisor:
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The area of Biomechanics is extremely broad, and before planning your electives, you should decide which of the two basic sub-disciplines is of greater interest to you:

• ***Mechanics of Tissues and Biomaterials*** – this area emphasizes understanding how biological and biomedical materials deform under load. You will be preparing yourself to work on tissue mechanics problems (e.g., how much does a vessel expand in response to a change in pressure, how much does a heart valve leaflet deflect under a given load, or how much does a tendon stretch given a certain amount of tension) as well as on mechanical aspects of biomaterials selection (e.g., what vascular graft or stent materials would provide a good match to the native tissue?).

• ***Kinematics and Biomechanical Design*** – this area emphasizes the design of biomechanical devices and how linkage systems behave. You will be preparing yourself to work on the design of mechanical systems for biomedical use (e.g., how one should design a knee brace to be as light as possible but still provide the necessary support) and to understand the dynamics of large-scale motions (e.g., what causes the characteristic features of the various gait irregularities and how can they be corrected?).

In either case, **your life will be a lot easier if you take AEM 3031 *Deformable Body Mechanics* in the spring of your junior year**. AEM 3031 is a gateway course for virtually the entire slate of upper-level AEM and ME courses, and it will be tough to take very many interesting courses your senior year if you have not already completed it.

The next page contains suggested courses. You will notice that some (such as AEM 3031) are listed under both sub-disciplines. *Please remember that all courses listed are merely suggestions*. You may take any cohesive set of classes that meet the requirements and are approved by the Emphasis Area Advisor and the Director of Undergraduate Studies. In particular, you may decide to mix and match classes from the two areas, which is certainly your right. Some courses that would be extremely relevant (e.g., ME 5243 *Advanced Mechanism Design*) are not listed because most students will not be able to take them in a 4-yr program; if you are staying at the U longer or are taking summer classes, other options may become available.

Also keep in mind that you may take up to six credits of Directed Research. This opportunity is one of the great advantages of attending a major research university.

Biomechanics (cont.)

Mechanics of Tissues and Biomaterials

Strongly Suggested Courses:

Dept	Number	Title	Prereqs	CR	E/S	Sem
AEM	3031	Deformable Body Mechanics	BMEn 3001, Math 2374, Math 2373 (or concur)	3	E	F/S
BMEn	5201	Advanced Biomechanics	BMEn 3001, ITUD	3	E	F

Additional Courses:

AEM	4501	Aerospace Structures	ITUD, AEM 3031	3	E	S
AEM	4502	Computational Structural Analysis	"C" in AEM 4501, ITUD	3	E	F
AEM	4511	Mechanics of Composite Materials	AEM 3031, ITUD	3	E	S
AEM	5501	Continuum Mechanics	ITUD 3031, Math 2243 or equiv (or conc)	3	E	F
BMEn	5001	Advanced Biomaterials	BMEn 3301 or MatS 3011	3	E	F
BMEn	5041	Tissue Engineering	ITUD	3	E	F
BMEn	5311	Advanced Biomedical Transport Processes	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
BMEn	5444	Muscle	Biol/ BioC 3021 or BioC 4331 or Phsl 3061	3	1/2	S
Math	4242	Applied Linear Algebra	Math 2243 or 2373 or 2573	4	S	F/S
MatS	4001	Thermodynamics of Materials	ITUD, Dept. consent	4	E	F
ME	5228	Introduction to Finite Element Modeling	ITUD, ME 3221, AEM 3031, CSci 1113, MatS 2001	4	E	F
ME	5241	Computer-Aided Engineering	ITUD, ME 3222, CSci 1113	4	E	F/S

Kinematics and Biomechanical Design

Strongly Suggested Courses:

Dept	Number	Title	Prereqs	CR	E/S	Sem
BMEn	5201	Advanced Biomechanics	BMEn 3001, ITUD	3	E	F
AEM	3031	Deformable Body Mechanics	BMEn 3001, Math 2374, Math 2373 (or concur)	3	E	F
ME	3221 †	Design and Manufacturing I †	ME 2011, AEM 3031, MatS 2001, [BMEn 3001, 3101]	4	E †	F/S

Additional Courses:

AEM	4501	Aerospace Structures	ITUD, AEM3031	3	E	**Sem**
BMEn	5311	Advanced Biomedical Transport Processes	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
IE	5511	Human Factors and Work Analysis	ITUD	4	E	F
Math	4242	Applied Linear Algebra	Math 2243 or 2373 or 2573	4	S	F/S
Math	4457	Methods of Applied Math I	Math 2243 or 2373 or 2574	4	E	F
ME	3222 †	Design and Manufacturing II †	ME 3221 (or conc), CSci 1113 , [BMEn 3001, 3101]	4	E †	F/S
ME	4031W	Basic Mechanical Measurements Lab	ME 3333 (or conc), IE 4521, [BMEn 3001, 3101]	4	E	F/S
ME	4231	Motion Control Lab	ME 4031W [BMEn 3001, 3101, 3401]	4	E	F/S
ME	5221	Computer-Assisted Product Realization	ME 3221, AEM 3031, CSci 1113, MatS 2001	4	E	F/S
ME	5228	Introduction to Finite Element Modeling	IT upper div	4	E	F
ME	5241	Computer-Aided Engineering	ITUD, ME 3222, CSci 1113	4	E	F/S
ME	5281	Analog and Digital Control	BMEn 3401	4	E	F

† These courses are required for the ME major and have a significant laboratory component with limited seating capacity. Consequently, the ME DUS will give priority to ME students and may not give permission to BME students for these courses.

PLEASE NOTE: Semester information subject to change. Always check the schedule of classes on OneStop for the most current course data.

Bioelectricity/Bioinstrumentation (BEI)

Emphasis Area Advisor:
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In bioelectricity / instrumentation (BEI), we seek to record, process, image, and control biomedical signals and develop instrumentation for biological research and medical applications. Specific examples of bioelectricity / instrumentation include cardiac pacemakers for restoring heart rhythm, brain –computer interfaces to link the brain and environment, and magnetic resonance imaging system for imaging the anatomy and functions of the brain and body. Past students with BEI emphasis area have gone to work in industry immediately following graduation, or to study in graduate school or medical school.

Dept	Number	Title	Prereqs	CR	E/S	Sem
BMEn	5101	Advanced Bioelectricity/Instrumentation	ITUD	3	E	S
BMEn	5401	Advanced Functional Biomedical Imaging	ITUD	3	E	F
BMEn	5151	BioMEMS and Medical Microdevices	Instructor consent	2	E	S
EE	3101	Circuits and Electronics Laboratory	EE 2002, EE 3115 (or conc.)	2	E	F/S
EE	3115	Analog and Digital Electronics	BMEn 3401 (or conc.)	4	E	F/S
EE	3161	Semiconductor Devices	ITUD, BMEn 3201, Phys 1302, Phys 2303 or Chem 1022	3	E	F/S
EE	3601	Transmission Lines, Fields, and Waves	BMEn 3201, [Math 2243 or 2373 or 2573], [Phys 1302 or 1402]	3	E	F/S
EE	4111	Advanced Analog Electronics Design	BMEn 3401, EE 3115	4	E	S
EE	4231	Linear Control Systems: Designed by Input/Output Methods	BMEn 3401, UDIT	3	E	F
EE	4233	State Space Control Systems Design	BMEn 3401, UDIT	3	E	S
EE	4541	Digital Signal Processing	BMEn 3401, EE 3025	3	E	F/S
EE	5545	Digital Signal Processing Design	EE 4541	3	E	S
EE	5621	Physical Optics	BMEn 3401, Dept. consent	3	E	S
Phys	2601	Quantum Physics	[Phys 2403H or 2503], [Math 2243 or 2373 or 2574H]	4	S	S
Phys	4002	Electricity and Magnetism	[PHYS 2303 or PHYS 2601 or Chem 3501 or Chem 3502], two sems soph math	4	S	S

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Biomedical Transport Processes (BTP)

Emphasis Area Advisor (EAA):
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BTP involves three fundamental processes: momentum transfer, mass transfer, and heat transfer. They share similar biophysical and mathematical descriptions and so are commonly taught within a single course, as we do in BMEn 3101 and its sequel, BMEn 5311.

Momentum transfer is what underlies flow fluid in the subject known as fluid mechanics. Applications of fluid mechanics in BME range from predicting blood flow in vessels, to flow of samples in "lab-on-chip" microfluidic systems, to flow of cell culture medium through tissue-engineered cartilage in bioreactors. Mass and heat transfer refer to the ability to deliver molecules and energy, respectively, from a source to a target. Applications of mass and heat transfer range from predicting blood oxygenation rates in capillaries from oxygen in lung alveoli and in hollow fibers from pure oxygen gas in "heart-lung machines," to movement of mRNA generated in the cell nucleus to cytoplasmic ribosomes.

While appropriate and accurate experimentation is also key on this subject, BTP is highly mathematical and computational in nature, since the basis of making such predictions is formulating and solving the equations that govern momentum, mass, and energy balances. This is reflected in the number of mathematical and computational ESE courses listed for this EA.

As suggested in the above applications, BTP is relevant in almost every physiological / cellular process and almost all medical devices. Thus, this EA is relevant for students interested in pursuing both employment and advanced studies upon graduation.

Suggested Courses:

Dept	Number	Title	Prereqs	CR	E/S	Sem
AEM	5251	Computational Fluid Mechanics	AEM 4201, CSci 1113, ITUD	3	E	F
BBE	4013	Transport in Biological Systems	[BBE 3013 (or conc) or ChEn 3701], CE 3502, BME3101, BME3401	4	E	S
BBE	4713	Biological Process Engineering	BBE4013 (or conc.) ITUD	3	E	S
BMEn	5041	Tissue Engineering	ITUD	3	E	F
BMEn	5311	Advanced Biomedical Transport Processes	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
BMEn	5351	Cell Engineering	BMEn 2501, CSCI 1107, [Math 2243 or Math 2373], ITUD	3	E	S
ChEn	4701	Advanced Undergraduate Applied Math I	ChEn 3102 or ChEn 4102, Dept. cons.	3	E	F
ChEn	4702	Advanced Undergraduate Rheology	BMEn 3101	2	E	S
ChEn	4704	Advanced Undergraduate Physical Rate Processes I: Transport	BMEn 3101	3	E	F
Math	4242	Applied Linear Algebra	Math 2243 or 2373 or 2573	4	S	F/S
Math	4512	Differential Equations with Applications	Math 2243 or 2373 or 2573	3	S	F/S
ME	3333	Thermal Sciences III (Heat Transfer)	ME 3332, [BMEn 3001, 3101]	3	E	F/S
ME	5228	Introduction to Finite Element Modeling	ITUD, ME 3221, AEM 3031, CSci 1113, MatS 2001	4	E	F
ME	5341	Case Studies in Thermal Engineering and Design	ITUD, ME 3321, ME 3322	4	E	S/F
ME	5344	Thermodynamics of Fluid Flow with Applications	ITUD, ME 3321, ME 3322	4	E	F
ME	5351	Computational Heat Transfer	ITUD, ME 3322	4	E	S

PLEASE NOTE: Semester information subject to change. Always check the schedule of classes on OneStop for the most current course data.

Biomaterials

Emphasis Area Advisors:
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Students in the emphasis area of Biomaterials are expected to become acquainted with the general principles of designing, synthesizing, processing, and characterizing biomaterials and learn to use biomaterials to solve problems in biology and medicine. Courses on life science, fundamentals of materials science and engineering, and interactions betweens materials and living elements are relevant. In completing this emphasis area, students should try to take Advanced Biomaterials (BMEn 5001). Since Polymeric Biomaterials have very broad applications, Polymers (ChE/MatS 4214) is recommended. Students who plan on immediate employment in industry are encouraged to take as many courses in MatS as possible to be competitive for available positions.

Suggested Courses:

Dept	Number	Title	Prereqs	CR	E/S	Sem
AEM	3031	Deformable Body Mechanics	BMEN 3001, Math 2374, Math 2373 (or concur)	3	E	F/S
AEM	4511	Composite Materials	AEM 3031, ITUD	3	E	S
AEM	4581	Mechanics of Solids	AEM3031, Math 2373, Math 2374, ITUD	3	E	F
BMEn	5444	Muscle	Bioc 3021 or 4331 or Phsl 3061	3	1/2	S
Biol	4004	Cell Biology	[BIOL 3021 or BIOC 3021 or BIOC 4331], [BIOL 4003 or BIOC 4332]	3	S	F/S
BMEn	5001	Advanced Biomaterials	BMEn 3301 or MatS 3011	3	E	F
BMEn	5041	Tissue Engineering	ITUD	3	E	F
BMEn	5201	Advanced Biomechanics	BMEn 3001, ITUD	3	E	F
BMEn	5212	Tissue Mechanics	BMEn 5201 or AEM 5501	2	E	S
BMEn	5311	Advanced Transport	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
BMEn	5351	Cell Engineering	BMEn 2501, CSCI 1107, [Math 2243 or Math 2373], ITUD	3	E	S
BMEn	5151	Intro to BioMEMS	Instructor consent	2	E	S
ChE/ MatS	4214	Polymers	BMEN 3301, [MatS 4001 or CHEN 4101], Dept. consent	3	E	S
GCD	4111	Histology	Biol 4004 (or conc)	4	S	S
MatS	3012	Metals	BMEn 3301, inst. consent	3	E	F
MatS	3801	Structural Characterization Lab	BMEn 3301, inst. consent	3	E	F
MatS	4001	Thermodynamics or Materials	ITUD, Dept. consent	4	E	F
MatS	4212	Ceramics	BMEn 3301, Dept. consent	3	E	F
MatS	4221	Materials Design and Performance	MatS 3012 or inst. consent	4	E	F
MatS	4301W	Materials Processing	MatS 4212, MatS 4214 (or conc)	4	E	St
MatS	4511W	Corrosion	BMEn 3301	4	E	F
MicB	4131	Immunology	[MicB 2022 or VPB 2022 or BIOL 2032 or VPB 2032 or VBS 2032 or 3301 or BIOL 3301], [BIOC 3021 or BIOL 3021 or BIOC 4331]	3	S	F
Phys	4911	Intro to Biopolymer Phys	[Phys 2303, 2403H, 2503] or Chem 3501 or Inst. cons.	3	1/2	S

t Space is extremely limited. Contact course instructor for permission to register.

PLEASE NOTE: Semester information subject to change. Always check the schedule of classes on OneStop for the most current course data.

Cell and Tissue Engineering (CTE)

Emphasis Area Advisor:
Prof. D. Odde
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In cell and tissue engineering (CTE) we seek to control biological function at the cell and tissue level. Specific examples of tissue engineering include bioreactors for controlled physical/chemical stimuli, drug and nutrient transport through tissue, and tissue mechanical properties. Specific examples of cell engineering include control of cell migration, division, growth, and death through therapeutic drugs or other molecular agents, such as those released from drug-eluting stents.

In completing this emphasis area, students should try to take both Cell Engineering (BMEn 5351) and Tissue Engineering (BMEn 5041). If students are most interested in working in the biomedical device industry upon graduation, they should be aware that there are at present relatively few bachelor degree-level positions that directly relate to CTE. Rather, most of the positions in CTE tend to be filled by PhD-level engineers, and so further study is usually required. If a student is considering further study, such as graduate or medical school, this emphasis area will be useful preparation, provided the student is intrinsically interested in CTE. Other emphasis areas can also serve to prepare students for further study.

Premed students should be aware that the "UMN Medical School recommended courses" (see http://www.meded.umn.edu/admissions/) in Biochemistry and Genetics can be taken towards the Cell and Tissue Engineering Emphasis Area. As a result, CTE is the EA that most directly allows the Medical School required and recommended courses to be satisfied.

Suggested Courses:

Dept	Number	Title	Prereqs	CR	E/S	Sem
AEM	3031	Deformable Body Mechanics	BMEN 3001, Math 2374, Math 2373 (or concur)	3	E	F/S
Biol	4003	Genetics	Bioc 3021 or Bioc 4331, Dept cons.	3	S	F/S
Biol	4004	Cell Biology	[BIOL 3021 or BIOC 3021 or BIOC 4331], [BIOL 4003 or BIOC 4332]	3	S	F/S
BioC	4025	Laboratory in Biotechnology	Bioc 3021 or Bioc 4331 or equiv	2	S	F/S
BMEn	5001	Advanced Biomaterials	BMEn 3301 or MatS 3011	3	E	F
BMEn	5041	Tissue Engineering	ITUD	3	E	F
BMEn	5201	Advanced Biomechanics	BMEn 3001, ITUD	3	E	F
BMEn	5311	Advanced Transport Processes	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
BMEn	5351	Cell Engineering	BMEn 2501, CSCI 1107, [Math 2243 or Math 2373], ITUD	3	E	S
ChEn	5751	Biochemical Engineering	BMEn 3101, [ChEn 3006 or 4006 (or conc)], [ChEn3102 or 4102 (or conc)]	3	E	S
GCD	4025	Cell Biology Lab	Biol 4004 (or conc)	2	S	S
GCD	4111	Histology: Cell and Tissue Organization	Biol 4004 (or conc)	4	S	S
GCD	4143	Human Genetics	Biol 3022 or Biol 4003 (or inst approval)	3	S	S
GCD	4161	Developmental Biology	Biol 4003, Biol 4004 (or conc) recom.	3	S	F
Kin	3027	Human Anatomy for Kinesiology Students	none	3	S	S
MatS	4512	Corrosion and Electrochemistry of Corrosion	BMEn 3301	4	E	F
MicB	4131	Immunology	[MicB 2022 or VPB 2022 or BIOL 2032 or VPB 2032 or VBS 2032 or 3301 or BIOL 3301], [BIOC 3021 or BIOL 3021 or BIOC 4331]	3	S	F/S

PLEASE NOTE: Semester information subject to change. Always check the schedule of classes on OneStop for the most current course data.

Medical Devices

Emphasis Area Advisor:
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The medical device area covers an extreme range from implantable coronary artery stents to refrigerator-sized blood testers. Some courses, such as Advanced Biomaterials, Computer-Aided Product Realization, Quality Engineering, Design and Manufacturing, and Designing Experiments could be helpful for any career in devices. The student interested in electronic devices (which can range from pacemakers to giant blood testers) might consider the EE courses covering Fundamentals, Microsystems, Microcontrollers, Communications, and Analog/Digital design. Someone considering work in the broad area of stimulation and monitoring (pacemakers to nerve stimulators to EKGs) would be wise to take advanced bioelectricity. For a career in external medical devices (such as cardiac assist, dialysis, or blood testers) the courses on Advanced Biomedical Transport, Electric Drives, Motion Control, Advanced Mechanisms Design, Stress Analysis/Sensing/Transducers, and Robotics are very helpful.

Suggested Courses:

Dept	Number	Title	Prereqs	Cr	E/S	Sem
BMEn	5001	Advanced Biomaterials	BMEn 3301 or MatS 3011	3	E	F
BMEn	5101	Advanced Bioelectricity and Instrumentation	ITUD	3	E	S
BMEn	5151	Biomedical MEMS	IT Senior	2	E	S
BMEn	5311	Advanced Biomedical Transport Processes	ITUD, ChEn 5103 or ME 5342 recom.	3	E	S
EE	2361	Introduction to Micro controllers	EE 2301, [EE 1301 or CSCI 1113 or CSCI 1901]	4	E	F/S
EE	3005	Fundamentals of Electrical Engineering	Math 2243, Phys 1302	4	E	F/S
EE	3006	Lab with EE 3005	Enroll. in EE 3005 allowed	1	E	F/S
EE	3115	Analog and Digital Electronics	BMEn 3401	4	E	F/S
EE	4111	Advanced Analog Electronics Design	BMEn 3401, EE 3115	4	E	S
EE	4341	Microproc. & Microcont. Syst. Design	EE2301, EE2361	4	E	S
EE	4501	Communications Systems	EE 3025	3	E	F
EE	4505	Lab with EE 4501	EE 4501 (or conc)	1	E	F
EE	4703	Lab with EE 4701	EE 4701 (or conc)	1	E	S
IE	5522	Quality Engineering and Reliability	IE 4521 or equiv, ITUD	4	E	S
MatS	4512	Corrosion and Electrochemistry of Corrosion	BMEn 3301	4	E	F
ME	3221	Design and Manufacturing I	ME 2011, AEM 3031, MatS 2001, [BMEn 3001, 3101]	4	E	F/S
ME	3222	Design and Manufacturing II	ME 3221 or conc.	4	E	F/S
ME	4231	Motion Control Laboratory	ME 4031W [BMEn 3001, 3101, 3401]	4	E	F/S
ME	5221	Computer-Assisted Product Realization	ME 3221, AEM 3031, CSci 1113, MatS 2001	4	E	F/S
ME	5228	Introduction to Finite Element Modeling, Analysis and Design	ITUD, ME 3221, AEM 3031, CSci 1113, MatS 2001	4	E	F
ME	5243	Advanced Mechanism Design	ITUD, ME 3222, basic kinematics & dynamics of machines; CAD packages such as Pro-E recomm.	4	E	F
ME	5286	Robotics	BMEn 3401, 3001, 3101	4	E	S
STAT	5303	Designing Experiments	[Stat 3022 or 4102 or 5021 or 5102] or inst. consent	4	E	F/S

PLEASE NOTE: Semester information subject to change. Always check the schedule of classes on OneStop for the most current course data.

Neural Engineering

Emphasis Area Advisor (EAA):
Prof. Tay Netoff
tnetoff@umn.edu

In Neural Engineering we use engineering principles to understand how the brain works and develop new technology to interact and treat the brain. The curriculum for this emphasis area is designed to teach you the basics of neuroanatomy and neurophysiology and the fundamentals of diseases such as Alzheimer's, Parkinson's, tinnitus, and epilepsy. You will also develop engineering skills such as signal processing, image processing, instrumentation and computational modeling as well as electrode design, amplifier and filter design, brain machine interfaces, cochlear implants, and deep brain stimulation. Students graduating from this emphasis area will be highly qualified for medical school, graduate school, or working in the burgeoning medical device industry dedicated to neural engineering. Please note that **it is strongly recommended that students interested in this EA take EE3115 their junior year.**

Dept	Number	Title	Prereqs	CR	E/S	Sem
BMEn	5411	Neural Engineering	BMEn 3401 recom.	3	E	F
BMEn	5101	Advanced Bioelectricity/Instrumentation	ITUD	3	E	S
BMEn	5351	Cell Engineering	BMEn 2501, CSCI 1107, [Math 2243 or Math 2373], ITUD	3	E	F
BMEn	5401	Advanced Functional Biomedical Imaging	ITUD	3	E	F
BMEn	5421	Introduction to Biomedical Optics	IT Senior	3	E	S
EE	3115	Analog and Digital Electronics	BMEn 3401 (or conc.)	4	E	F/S
EE	4111	Advanced Analog Electronics Design	BMEn 3401, EE 3115	4	E	S
EE	4231	Linear Control Systems: Designed by Input/Output Methods	BMEn 3401, UDIT	3	E	F
EE	4541	Digital Signal Processing	BMEn 3401, EE 3025	3	E	F/S
EE	5545	Digital Signal Processing Design	EE 4541	3	E	S
NSCI	1001	Intro to Neuroscience (for non-majors)	None	3	S	S
NSCI	3101	Introduction to Neuroscience I: From Molecules to Madness	BioC 3021 (or conc) or BioC 4331 (or conc)	3	S	F
NSCI	3102W	Introduction to Neuroscience II: Biological Basis of Behavior	NSCI 3101(B+ recomm) or BIOL 3101 or PHSL 3101	3	S	S
NSCI	4105	Neurobiology Laboratory I	[NSCI 3101 or Biol 3101 or Phsl 3101], [3102W or Biol 3102W], inst. cons.	3	S	F
NSC	5201	Computational Neuroscience I: Membranes and Channels	Calc. through Diff. Eq.	3	S	F
NSC	5202	Theoretical Neuroscience: Systems and Information Processing	[NSCI 3101, NSCI 3102W] recom.	3	S	S
NSC	5461	Cellular and Molecular Neuroscience (This is the grad version of NSCI 3101, one or the other should be taken)	Inst. consent	4	S	F
MATH	5447	Theoretical Neuroscience	Math 2243 or 2373 or 2574	4	S	F

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