BACHELOR OF CHEMICAL ENGINEERING PROGRAM

UNDERGRADUATE CURRICULUM GUIDE

Department of Chemical Engineering
and Materials Science

University of Minnesota

151 Amundson Hall
421 Washington Avenue, SE
Minneapolis, MN 55455

Updated February 2008

Undergraduate Student Services:

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CHEMICAL ENGINEERING AVM 2/6/2008

Freshman Year (many students take a lib ed elective in the May or Summer term)

	Fall Semester	crs		Spring Semester	crs
	Chem 1021 Chem Prin I	4		Chem 1022 Chem Prin II *[Chem 1021]*	4
	Math 1371 (or 1271) Calc I *(1371 Fall only)*	4		Math 1372 Calc II *[C or better in 1271 or 1371]*	4
	Phys 1301 Intro Phys I *[&Math 1271 or &Math 1371]*	4	*UD*	Phys 1302 Intro Phys II *[&Math 1272 or &1372, Phys 1301]*	4
UD	EngC or Rhet Freshman Writing - Lib Ed*	3 or 4		Lib Ed** (e.g. Biol 1009)	3 or 4

***Freshman composition is required for upper division.**
**** Biol 1009 is recommended in the first or second year.**

Sophomore Year

	Fall Semester	crs		Spring Semester	crs
	Chem 2301 Org Chem I *[Chem 1022]*	3	*UD*	Chem 2302 Org Chem II *[Chem 2301]*	3
$	Chem 3502 Quantum Chem *11:15* *[1022, Math 1272 or 1372, Phys 1302]*	3	*UD*	Chem 3501 Chemical Thermo *11:15* *[Chem 1022, Math 2263 or 2374, Phys 1302]*	3
$	MatS 3011 Intro MatSci *2:30* *[Chem 1021, Math 1272, Phys 1302]*	3	*UD*	Math 2373 Lin alg/diff eqs *[Math 1272 or 1372]*	4
UD	Math 2374 Multivar. Calc and Vec An *[Math 1272 or 1372]*	4	*UD*	ChEn 4001 Matl and En Bal *3:35* *[Chem 2302 or &, Chem 3501 or &, Math 2374 or &, Math 2373 or &, Phys 1302]*	4
	Lib Ed*** (e.g. Hist)	3 or 4		Lib Ed*** (e.g., Soc Sci I)	3

& Registrar symbol for concurrent registration

*** For eng degrees, the two Soc Sci, the Hist, the Lit, and the Other Hum lib eds must fill both a core and a theme to guarantee 4-year degree program. These may be taken S/N.

For some courses, prereqs and MWF lecture times are shown in italics.
Shaded courses are offered only once a year.

UD You must have at least a 2.60 technical GPA for admission to upper division Chemical Engineering. This GPA includes all calculus, physics, chemistry, computer science, and engineering courses. In addition, courses with UD need to be completed before you apply, unless you have at least a 2.90 tech GPA and the courses in progress.

For students with ChEn 4001 on or before Spring 2008.

Junior Year

	Fall Semester	crs	Spring Semester	crs
	Chem 2311 Organic Lab *[Chem 2302 or &2302]*	4	Chem 4121 Analyt Chem 12:20 *[2302, 2311, 3501, ChEn only]* Earlier Chem 4121 or 2101/2111 also okay.	3
	ChEn 3701 Biomolec Engrg *8* *[Chem 2302, Math 2373, 4001]*	3	ChEn 4006 Mass Tran & Sepns *1:25 [UD ChEn, ChEn 4001, 4005, 4101]*	4
	ChEn 4005 Fluid and Heat Transprt *10:10 [UD ChEn, 4001]*	4	ChEn 4102 React Kin & Eng. *11:15 [UD ChEn, 4001, 4101]*	4
	ChEn 4101 Chem Eng Thermo *1:25 [UD ChEn, 4001, Chem 3501]*	4	ChEn 4201 Comp Mthds in ChEn *10:10 [UD ChEn, 4001, 4005, 4006 or &]*	3
	Chem/ChE dbl mjrs should take Chem 4701 12:20 this semester and may delay ChEn 3701		Lib Ed*** (e.g. Soc Sci II)	3

Senior Year

	Fall Semester	crs	Spring Semester	crs
	ChEn 4401W Chem Eng. Lab I *12:20 [UD ChEn, 4005, 4006, 4101, 4102, Chem 2311,Chem 4121, Engl Comp]*	3	ChEn 4402W Chem Eng Lab II *8 Mon [UD ChEn, 4006, 4101, 4401W]* switches to 9 Spring 09	2
	ChEn 4501W Chem Eng Proc Des I *9:05 [UD ChEn, 4005, 4006, 4101, 4102, 4201 Chem 2311, Chem 4121, Engl Comp]*	3	ChEn 4502W Chem Eng Proc Des II *8 Wed, Fri [UD ChEn, 4501]* switches to 9 Spring 09	2
@	Tech elective I	3	ChEn 4601 Process Control *9:05 [UD ChEn, ChEn 4102]* switches to 8 Spring 09	3
@	Tech elective II	3	@ MatS 4214 Polymers ✱ *[UD, MatS 3011, [MatS 4001 or ChEn 4101]]* MatS 4214 can be taken earlier	3
	Lib Ed*** (e.g. Lit)	3	@ Tech elective III	3
			Lib Ed*** (e.g. Art/Hum)	3

Courses with a double-lined border are Writing Intensive (WI) courses.
Those shown here more than suffice for the WI requirements.

$ Recommended at this position in the plan, but can be delayed with advisor approval.

@ Preapproved or with DUS/ChEn-advisor approval. Several restrictions apply.
Max 2 cr. nontechnical, max 6 cr. transfer, even if approved.
Tech electives must be 9 cr,. ✱ in addition to MatS 4214 (or DUGS approved substitute to MatS 4214).
As of 2007-08 academic year ChEn 4214 is offered in the Spring.

2/6/2008

CHEMICAL ENGINEERING

TO BE PUT INTO EFFECT WITH CHEN SOPHOMORES READY FOR ChEn 2001 IN FALL 08 (i.e., Class of 2011 - Jrs in Fall 09, Srs in Fall 10)

Department version.

Freshman Year (many students take a lib ed elective in the May or Summer term)

Fall Semester	crs	Spring Semester	crs
Chem 1021 Chem Prin I	4	Chem 1022 Chem Prin II *[Chem 1021]*	4
Math 1371 (or 1271) Calc I *(1371 Fall only)*	4	Math 1372 Calc II *[C or better in 1271 or 1371]*	4
Phys 1301W Intro Phys I *[&Math 1271 or &Math 1371]*	4	*UD* Phys 1302W Intro Phys II *[&Math 1272 or &1372, Phys 1301]*	4
UD Freshman Writing - Lib Ed	3 or 4	Lib Ed* (e.g. Biol 1009)	3 or 4

*** Biol 1009 is recommended in the first year.**

Junior Year

Fall Semester (change Fall 09)	crs	Spring Semester (change Spring 10)	crs
Chem 2311 Organic Lab *[Chem 2302 or &2302]*	4	ChEn 3401W JrChEnLab 12:20 *UD, 3006 or &, 3102 Chem 2121 or & or eq.)]*	2
ChEn 3701 Biomolec Eng *8* *[Chem 2302, Math 2373 or &, **2001**, h.s. biology rec'd]*	3	**ChEn 3006** Mass Tran & Sepns *1:25 [UD ChEn, **2001**, 3005, 3101]*	4
ChEn 3005 Fluid and Heat Transprt *10:10 [UD ChEn, **2001**]*	4	**ChEn 3102** React Kin & Eng. *11:15 [UD ChEn, **2001**, 3101]*	4
ChEn 3101 Chem Eng Thermo *1:25 [UD ChEn, **2001**, Chem 3501]*	4	**ChEn 3201** Comp Mthds in ChEn *10:10 [UD ChEn, **2001**, 3005, 3006 or &]*	3
Chem/ChEn dbl majors should take Chem 4701 12:20 this semester with Chem dept. approval and may delay ChEn 3701		Lib Ed*** (e.g. Soc Sci II)	3

Sophomore Year

Fall Semester (change Fall 08)	crs	Spring Semester (change Spring 09)	crs
Chem 2301 Org Chem I *[Chem 1022]*	3	*UD* Chem 2302 Org Chem II *[Chem 2301]*	3
UD **ChEn 2001** Matl and En Bal *3:35?* *[Chem 2301 or &, Math 2374 or &, Phys 1302 or &]*	4	*UD* Chem 3501 Chemical Thermo *11:15* *[Chem 1022, Math 2263 or 2374, Phys 1302]* Chem 3501 can be taken earlier	3
$ MatS 3011 Intro MatSci *2:30* *[Chem 1021, Math 1272, Phys 1302]*	3	*UD* Math 2373 Lin alg/diff eqs *[Math 1272 or 1372]*	4
UD Math 2374 Multivar. Calc and Vec An *[Math 1272 or 1372]*	4	*UD* **Chem 2121** Analyt Chem 12:20 *[2301, 3501 or &, ChEn only]* Until Sum'10 Chem 2101 + 2111 can subsittute.	3
Lib Ed*** (e.g. Hist)	3	Lib Ed*** (e.g., Soc Sci I)	3

& Registrar symbol for concurrent registration

Bold-bordered courses are offered only once a year.

*** For eng degrees, the two Soc Sci, the Hist, the Lit, and the Other Hum lib eds must fill both a core and a theme to guarantee 4-year degree program. These may be taken S/N.

UD You must have at least a 2.60 technical GPA for admission to upper division Chemical Engineering. This GPA includes all calculus, physics, chemistry, computer science, and engineering courses. In addition, courses with UD need to be completed before you apply, unless you have at least a 2.90 tech GPA and the courses in progress.

Senior Year

Fall Semester (change Fall 10)	crs	Spring Semester (change Spring 11)	crs
ChEn 4401W Senior Chem Eng. Lab *12:20 [UD ChEn, 3005, 3006, 3101, 3102 3401,Chem 2121, Chem 2311, Fresh Writing]*	3	ChEn 4502W Chem Eng Proc Des II *9 Wed, Fri [UD ChEn, 4501]*	2
ChEn 4501W Chem Eng Proc Des I *8 [UD ChEn, 3005, 3006, 3101, 3102, 3201 Chem 2311, Chem 2121, Fresh. Writing]*	3	Chem 3502 Quantum Chem *10:10* *[Chem1022, Math 1272 or 1372, Phys 1302]* Chem 3502 can be taken earlier	3
ChEn 4601 Process Control *9:05 [UD ChEn, ChEn 3102]*	3	@ MatS 4214 Polymers *2:30* ✱ *[UD, MatS 3011, [MatS 4001 or ChEn 3101]]* MatS 4214 can be taken earlier	3
@ Tech elective I	3	@ Tech elective II	3
Lib Ed*** (e.g. Lit)	3	@ Tech elective III	3
		Lib Ed*** (e.g. Art/Hum)	3

Reformed course numbers in bold.

For some courses, prereqs and MWF lecture times are shown in italics.

Course changes approved in Sept. 2007

$ Recommended at this position in the plan, but can be delayed with advisor approval.

@ Preapproved or with DUS/ChEn-advisor approval. Several restrictions apply.
Max 2 cr. nontechnical, max 6 cr. transfer, even if approved.
Tech electives must be 9 cr., ✱ in addition to MatS 4214 (or DUGS approved substitute to MatS 4214).
As of 2007-08 academic year MatS 4214 is offered in the Spring.

2/6/2008

I. Preface

This program bulletin is intended to guide current Chemical Engineering majors and to inform prospective CHEN majors. It should be used in conjunction with the Undergraduate Catalog found on the Web at <http://www.catalogs.umn.edu/ug/index.html>. Pay particular attention to the section of the Undergraduate Catalog devoted Institute of Technology policies and on the Chemical Engineering program, which can be found at <http://www.catalogs.umn.edu/programs.html>. Click on "See All Undergraduate Majors", then on "Chemical Engineering" or on "Institute of Technology", depending on what you are looking for.

The Institute of Technology (IT) website <http://www.it.umn.edu> is also a valuable source of official information on all aspects of academic and student life. Click on the link for "Current Students". At this site you will find information dealing with college-wide policy and procedures such as the honors program, GPA requirements for program entrance, Liberal Education Requirements, dropping and adding classes, entering Upper Division, and changing majors.

II. What Do Chemical Engineers Do?

The chemical engineer develops a chemical process from its laboratory beginning through semi-works equipment to full-scale production. Chemical engineering is based on applications of chemistry, biology, physics, materials science, mathematics and economics. The chemical engineering curriculum includes the study of applied mathematics; material and energy balances; properties and physics of gases, liquids, and solids; fluid mechanics; heat and mass transfer; thermodynamics; chemical and biological reaction kinetics and reactor design; and the integrating subjects of process design, control, and economic optimization. Because of this broad-based foundation, emphasizing both basic and engineering science, the chemical engineer is considered the universal engineer.

Chemical engineers work on a wide variety of projects: basic and applied research, product development, design and modification of processes and equipment, and plant operation. Some enter sales, marketing, management, consulting, government agencies, consulting, or teaching. Because of the breadth and flexibility of the chemical engineering major, it is chosen by some students who plan to pursue graduate study in medical sciences, materials science, business administration, or patent and environmental law.

Chemical engineering deals with operations such as materials handling, mixing, fluid flow and metering, extrusion, coating, heat exchange, filtration, drying, evaporation, distillation, absorption, extraction, ion exchange, combustion, catalysis, and processing in chemical and biochemical reactors. These operations are vital to the commercial success of industries based on the chemical and physical transformation of matter. While of course a chemist or a biologist used these operations in a laboratory, developing these operations for complex and large-scale industrial processes requires a complete and quantitative understanding of the chemical engineering principles as well as the scientific principles on which the operations rest.

Because many industries are based on chemical and physical transformation of matter, the chemical engineer is much in demand. He or she may work in the manufacture of inorganic products such as acids, alkalis, ammonia, fertilizers, paint pigments, ceramics, semiconductors and other electronic materials; in the manufacture of organic products such as polymer fibers, films, coatings, textiles, cellulose, paper, dyes, explosives, rubber, rocket propellants, solvents, plastics, agricultural chemicals, pharmaceuticals, coal-based fuels, petrochemicals; or in the manufacture of materials such as graphite, calcium carbide, abrasives, or those in wet and dry batteries, fuel cells, and more complex materials systems; in the electroplating, metallurgical, and materials processing industries; in food processing; in the fermentation industry for the production of antibiotics, feed supplements, and other biochemical products; or in the field of biotechnology, where applications range from utilization of the activities of microorganisms and cultured cells, to enzyme engineering, to the manufacture of foods, and in the biomedical field to the design of prosthetic devices and artificial human organs. Chemical engineers are also particularly well suited to

dealing with problems associated with the disposal of industrial wastes and other forms of pollution, as well as with environmental protection. And of course chemical engineering underlies most of the energy field, including the efficient production and utilization of coal, petroleum, natural gas, tar sand, oil shale, geothermal deposits, and nuclear energy.

III. Chemical Engineering Program Objectives and Outcomes

Program Educational Objectives (PEO's)

To provide educational experiences which challenge students to:

1. learn the scientific and engineering principles underlying the six major elements of chemical engineering: balances of material and energy; thermodynamics of physical and chemical equilibria; transport of heat, mass, and momentum; reaction kinetics and reactor analysis; separation operations; and process dynamics and control.

2. apply and integrate knowledge of the elements of chemical engineering to identify, formulate, and solve chemical process design problems.

3. learn to use and apply modern experimental and computational techniques in chemical engineering.

4. conduct experiments, including: design of experiment, execution and recording, analysis and interpretation of results, and professional reporting of results.

5. prepare for a career in chemical engineering and related fields by developing communication skills and coming to understand the importance of lifelong learning, professionalism, and ethical responsibility.

Program Outcomes (PO's) (adapted to Chemical Engineering from ABET Criteria <http://www.abet.org/>**)**

Graduates who have:

1. an ability to apply scientific and engineering principles underlying the major elements of chemical engineering.

2. an ability to design, conduct, analyze, and report on experiments and computational projects in chemical engineering.

3. an ability to apply and integrate the major elements of chemical engineering to formulate and solve chemical process design problems.

4. an ability to work in teams, including a beginning ability to work in multi-disciplinary teams.

5. an appreciation of the importance of professional and ethical responsibility (ABET f) and of learning and applying further scientific and engineering principles throughout their career.

6. an ability to communicate effectively.

7. a beginning understanding of the impact of engineering solutions on society, including safety, economic, and environmental impacts, and of the importance of learning more in these areas throughout their career.

8. an introduction to contemporary issues in chemical engineering.

IV. Requirements for the BChE Degree

To earn a Bachelor of Chemical Engineering degree one must complete the following requirements, in addition to meeting the University's liberal education requirements. The degree program is fully accredited by the Accreditation Board for Engineering and Technology (ABET).

Lower Division

Successfully complete the pre-chemical lower division program of chemistry, mathematics, physics and writing proficiency courses as listed in the semester course plan for the first two years. A slightly different program may satisfy this requirement, as in the case of a student who transfers from another curriculum or from another university, but only with the approval of the IT Student Services Office (this would be evaluated upon consideration for admission into upper division). All required lower division chemistry, physics, and mathematics courses must be taken on the A/F grade basis.

As you near completion of these courses in the Spring Semester of your sophomore year, you should apply to upper division Chemical Engineering program. You can find the application online at <http://www.it.umn.edu/forms/index.html>. Applications and attachments are turned in to 130 Lind Hall. The minimum requirements for admission to upper division Chemical Engineering include a technical GPA of 2.6 or better, and completion of the prerequisites. See Upper Division application for actual course numbers. If the final prerequisites are in progress, a technical GPA of 2.9 is required.

If you are transferring into the upper division Chemical Engineering program from another school, you must apply to Institute of Technology (IT) through the Office of Admissions <http://admissions.tc.umn.edu/admissioninfo/trans.html>. The IT website will provide additional transfer information <http://www.it.umn.edu/prospective/transfer.html>.

It is required that you have completed at least the first year curriculum. Transfer students should pay attention to the "Transferring Credit" website <http://www.it.umn.edu/prospective/transferring_credit.html> to determine course equivalencies located under the "Technical course transfer guide". The site also includes transfer plans for various schools under "Transfer Plans". Links are provided for US and International colleges and universities. In very rare instances students are admitted to upper division provisionally, contingent on completion of the remaining requirements. The student must complete the remaining requirements in the coming semester. If you have questions, you are encouraged to write, call or make an appointment to visit IT Student Services (130 Lind, 612-624-8504).

Upper Division

To complete the BChE degree requirements one must finish the upper division courses in the Chemical Engineering curriculum. One must complete at least 128 semester credits, including 48 credits of upper division CHEN requirements, and 12 credits of technical electives.

V. Scheduling Your Program and Using the Plan to Graduation

At the beginning of this brochure you will find attached two generic, ideal schedules of coursework if you start as a Freshman at the U of MN – Twin Cities. The difference is based on when you started your coursework. They are also available online <http://www.cems.umn.edu/undergrad/chen.htm> and then select between "Typical Plan for those graduating 2010 or before" or "Typical Plan for those graduating 2010 or later". Following this schedule you should be able to obtain your BChE degree in four years with no summer school. Your own situation may lead you to depart from this generic schedule, particularly as you plan your Liberal Education classes and your technical electives.

In planning your program, remember that many courses are offered only once a year, either Fall or Spring, but not both. In addition, these classes may have prerequisites that must be satisfied before attempting your intended courses. Finally, you must make sure the courses you intend do not meet at the same time. Department and University policy prohibits taking two courses offered with overlapping class hours.

Using the UM Graduation Planner
Each course in the Chemical Engineering program uses concepts from previous courses. Therefore it is of the utmost importance that the courses be taken in their proper sequence. The Graduation Planner <http://plan.umn.edu> is an on-line form used to facilitate the advising process and to ensure that you plan your progress to graduation. If you are not sure which technical electives you wish to take, you can note in the comments section that you plan to take X number of credits in the term as technical electives. When completing the form, be sure to include necessary coursework to make up for missing high school preparation requirements if applicable. Newly-admitted upper division students are required to fill out the graduation planner, and attend a mandatory information meeting. At that point, the hold on your record will be pushed back or removed and you will be able to register for the upcoming semester.

You must use the most current class schedules to know what semesters and class-times correspond to courses you are planning. You must ensure that you will have no class-time conflicts and that you will have the prerequisites for your planned courses. (Instructor permission may be given when adequate preparation is clear.)

You may instead or in addition choose to complete the departmental Plan to Graduation. For this, go to: <*https://www.cems.umn.edu/dept/undergrads/chenplanner/preview.php*>.

Please be sure to fill out semesters for all the courses you plan to take, including technical electives. You may revise your plan at any time after submitting it.

IMPORTANT: The APAS is the officially recognized tracking of your progress toward the degree. The Plan to Graduation is merely a tool to help you plan to fulfill all the requirements on the APAS. See Ms. Laura Ericksen or Prof. Alon McCormick to ensure your APAS is correct.

VI. Advising and Technical Electives

Advising on routine or probationary upper division Chemical Engineer matters is usually done by Prof. Alon McCormick, Prof. Caretta or Ms. Laura Ericksen.

In addition, when selecting your technical electives you will choose an advisor (determined by the associated emphasis area, as described below). It is important for you to talk with a professor who can help you think about career paths and elective course choices. The professors are more than happy to talk over your plans! If you have trouble catching them by phone or by dropping by their offices, try going to their offices during their office hours to suggest an appointment time, or e-mail them for an appointment.

When you graduate, you will need one or more faculty members as references for job or graduate school applications; advising is a good way to get to know the faculty and for them to get to know you. (Most graduate schools require three academic reference letters.) When requesting letters of recommendation or putting faculty names on your resume as prospective references be sure to a) send the faculty member an e-mail requesting that they serve this function; b) provide the faculty member all the materials (e.g. resume, essay, etc.); c) if a letter is requested, provide stamped, addressed envelopes.

International students with questions related to their international standing should contact Adam Pagel (105 Lind; pagel@umn.edu; 612-624-8013). He can help you take advantage of opportunities available to, or responsibilities incumbent upon, the international student.

Choosing technical electives
You must take 12 semester-credits of technical elective courses. This is usually accomplished by taking four 3-credit courses, and at least two of these courses must be science or engineering courses at the 4000-level or above. One of your technical electives must be ChEn 4214 Polymers, unless we approve a substitution. The substitution of another polymers course will viewed more favorably than other requests. Materials Science or Chemistry, except in the rare case when a suitable substitute is approved by the

DUGS and your advisor. You may apply up to 2 credits of directed research toward your technical electives if approved as such by your advisor*. At least six credits of your non-polymer technical electives must be taken at the University of Minnesota. *N.B.*: Only with special permission will transferred courses be allowed for technical electives. At least half of the technical electives must be upper division approved U of M courses.

Your advisor is the faculty person associated with the emphasis are you choose from the list below. Under each group heading is a list of courses already approved by the emphasis advisor. You must get approval from your advisor (using a Form 1014 Technical Elective Approval Form, obtained from Laura Ericksen in 151BB Amundson) to use other courses as CHEN technical electives. If you wish to select electives from more than one emphasis area your emphasis will be "General" and Prof. McCormick will be your advisor.

*For directed research or directed studies to be considered for tech elective credit you must file a final report with Ms. Laura Ericksen in 151BB Amundson. To start the process, get a form 2010 Research as Technical Elective Approval Form from Ms. Ericksen.

Before selecting technical electives read the five points below very carefully.

- All Technical Electives must be taken A-F.
- If you are pulling courses from different areas of emphasis, you must have approval of the Director of Undergraduate Studies, Prof. Alon McCormick.
- If you are a senior ChEn major and do not have exact pre-requisites for a desired course may contact the department offering the course and at that department's discretion obtain permission numbers. The department often gives it, if you have your ChEn adviser's recommendation.
- The term list is when it is most likely to be offered. Check the online class schedule to confirm actual offerings each term.
- Information below is taken from the online catalog in December 2007. If the information on the online catalog changes, it is the definitive source. It is in your best interest to confirm the below information. The website is <http://onestop2.umn.edu/courses/designators.jsp?institution=UMNTC>

Biomedical Engineering – Tranquillo

You must take into consideration the five points on page 9.

NOTE! BMEN 3301 and 3101 will NOT be approved as ChEn technical electives.

BMEN 5001 **- Advanced Biomaterials** Fall
(3.0 cr; Prereq-3301 or MatS 3011 or grad student or #; A-F or Aud, fall, every year)
Commonly used biomaterials. Chemical/physical aspects. Practical examples from such areas as cardiovascular/orthopedic applications, drug delivery, and cell encapsulation. Methods used for chemical analysis and for physical characterization of biomaterials. Effect of additives, stabilizers, processing conditions, and sterilization methods.

BMEN 5041 **- Tissue Engineering** Fall, Spring
(3.0 cr; Prereq-IT upper div or grad student or med student or #; fall, spring, every year) fall, spring
Fundamentals of wound healing and tissue repair; characterization of cell-matrix interactions; case study of engineered tissues, including skin, bone marrow, liver, vessel, and cartilage; regulation of biomaterials and engineered tissues.

BMEN 5371 **- Biomedical Applications of Heat Transfer in Humans** Spring, even years
(3.0 - 4.0 cr [max 4.0 cr]; Prereq-Phsl 3061, Phsl 3071, Phsl 5061; spring, even years)
Overview of physiology underlying thermoregulation in humans, clinical applications of heat transfer in humans, framework for design project.

BMEN 5501 **- Biology for Biomedical Engineers** Fall, Spring, offered when feasible
(3.0 - 4.0 cr [max 4.0 cr]; Prereq-Engineering upper div or grad student; fall, spring, offered when feasible)
Concepts of cell/tissue structure/function. Basic principles of cell biology. Tissue engineering, artificial organs. (Non-BME majors can also take the associated lab on a space-available basis.)

BIOL 4004 **- Cell Biology** Fall, Spring, Summer
(3.0 cr; Prereq-[3021 or BIOC 3021 or BIOC 4331], [4003 or BIOC 4332]; fall, spring, summer, every year)
Processes fundamental to cells. Emphasizes eukaryotic cells. Assembly/function of membranes/organelles. Cell division, cell form/movement, intercellular communication, transport, secretion pathways. Cancer cells, differentiated cells.

PHSL 5061 **- Principles of Physiology for Biomedical Engineering** Fall
(4.0 cr; Prereq-Biomedical engineering grad, one yr college chem and physics and math through integral calculus; fall, every year)
Human physiology with emphasis on quantitative aspects. Organ systems (circulation, respiration, renal, gastrointestinal, endocrine, muscle, central and peripheral nervous systems), cellular transport processes, and scaling in biology.

Biomolecular Engineering – Hu

You must take into consideration the five points on page 9.

BIOC 3021 **- Biochemistry** Fall, Spring, Summer
(3.0 cr; =[BIOC 6021]; Prereq-[Biol 1002 or 1009], Chem 2301; fall, spring, summer, every year)
Fundamentals of biochemistry including structure and function of proteins, nucleic acids, lipids and carbohydrates; metabolism and regulation of metabolism; quantitative treatments of chemical equilibria, enzyme catalysis and bioenergetics; the chemical basis of genetic information flow.

NSCI 3101 **- Introduction to Neuroscience I: From Molecules to Madness** Fall
(3.0 cr; =[BIOL 3101, PHSL 3101]; Prereq-BioC 3021 or & BioC 3021 or BioC 4331 or & BioC 4331 recommended; A-F or Aud, fall, every year)
Basic principles of cellular/molecular neurobiology and nervous systems.

BIOL 4003 **- Genetics** Fall, Spring, Summer
(3.0 cr; =[GCD 3022]; Prereq-[[BIOC 3021 or BIOC 4331], [any CBS major or major in [animal science or applied plant science or BA biology or BA microbiology or nutrition or physiology or biology/society/environment]]] or #; fall, spring, summer, every year)
Introduction to the nature of genetic information, its transmission from parents to offspring, its expression in cells/organisms, and its course in populations.

BIOL 4004 **- Cell Biology** Fall, Spring, Summer
(3.0 cr; Prereq-[3021 or BIOC 3021 or BIOC 4331], [4003 or BIOC 4332]; fall, spring, summer, every year)
Processes fundamental to cells. Emphasizes eukaryotic cells. Assembly/function of membranes/organelles. Cell division, cell form/movement, intercellular communication, transport, secretion pathways. Cancer cells, differentiated cells.

BMEN 5001 **- Advanced Biomaterials** Fall
(3.0 cr; Prereq-3301 or MatS 3011 or grad student or #; A-F or Aud, fall, every year)
Commonly used biomaterials. Chemical/physical aspects. Practical examples from such areas as cardiovascular/orthopedic applications, drug delivery, and cell encapsulation. Methods used for chemical analysis and for physical characterization of biomaterials. Effect of additives, stabilizers, processing conditions, and sterilization methods.

BMEN 5041 **- Tissue Engineering** Fall, Spring, Summer
(3.0 cr; Prereq-IT upper div or grad student or med student or #; fall, spring, every year) fall, spring
Fundamentals of wound healing and tissue repair; characterization of cell-matrix interactions; case study of engineered tissues, including skin, bone marrow, liver, vessel, and cartilage; regulation of biomaterials and engineered tissues.

CHEN 5751 **- Biochemical Engineering** Spring
(3.0 cr; Prereq-4002, & 4003, & 4102; A-F or Aud, spring, every year)
Chemical engineering principles applied to analysis/design of complex cellular/enzyme processes. Quantitative framework for design of cells for production of proteins, synthesis of antibodies with mammalian cells, or degradation of toxic compounds in contaminated soil.

CHEN 5753 **- Biological Transport Processes** Spring
(3.0 - 4.0 cr [max 4.0 cr]; =[BMEN 5311, ME 5381]; Prereq-4003 or ME 3322; A-F or Aud, spring, every year)
Introduction to fluid, mass, and heat transport in biological systems. Mass transfer across membranes, fluid flow in capillaries, interstitium, veins and arteries. Heat transfer in single cells and tissues. Whole organ and body heat transfer issues. Blood flow and oxygenation. Heat and mass transfer in respiratory system. Biotransport issues in artificial organs, membrane oxygenators, and drug delivery applications.

CHEN 5759 **- Principles of Mass Transfer in Engineering and Biological Engineering** Fall
(2.0 cr; Prereq-4002; A-F or Aud, fall, every year)
Principles of mass transfer in gases, liquids, biological and macromolecular solutions, gels, solids, membranes, and capillaries. Porous solids interaction between mass transfer and chemical reaction. Applications in biological, environmental, mineral, and chemical engineering systems.

MICB 3301 **- Biology of Microorganisms** Fall, Spring
(5.0 cr; =[BIOL 2032]; Prereq-[Biol 1002 or Biol 1009], Chem 2301, & Chem 2302; A-F or Aud, fall, spring, every year)
Taxonomy, anatomy, physiology, biochemistry, pathogenesis, immunology, ecology of microbes. Molecular structure in relation to bacterial function/disease. Includes lab.

MICB 4121 **- Microbial Ecology and Applied Microbiology** Spring
(3.0 cr; =[ES 4121, SOIL 4121]; Prereq-3301; A-F or Aud, spring, every year)
Evolution/structure of microbial communities. Population interaction within ecosystems. Quantitative/habitat ecology. Biogeochemical cycling. Molecular microbial ecology, gene transfer in the environment. Molecular phylogeny of microorganisms. Application of microbes in agriculture. Production of commodity chemicals, drugs, and other high-value products.

MICB 4131 **- Immunology** Fall, Spring
(3.0 cr; Prereq-[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]; fall, spring, every year)
Molecular, genetic, and cellular bases for humoral/cell-mediated immunity. Innate immunity. Antigen recognition by B and T lymphocytes. Interactions between lymphocytes and other cells of immune system. Cytokines. Immunoregulation. Key aspects of clinical immunology.

Chemistry – Frisbie or Norris

You must take into consideration the five points on page 9.

CHEN 4214 **- Polymers** Spring
(3.0 cr; Prereq-Grade of at least C in MatS 3011, ChEn major upper division or #; spring, every year)
Polymer structure-property relations: structure/morphology of crystalline/amorphous states. Crystallization kinetics. Vitrification and the glass transition. Mechanical properties, failure, permeability, optical/electrical properties, polymer composites, effect of processing on properties.

CHEN 4708 **- Advanced Undergraduate Chemical Rate Processes: Analysis of Chemical Reactors** Spring
(3.0 cr; Prereq-4102, ChEn major upper division; A-F or Aud, spring, every year)
Design of reactors for heat management, with catalytic processes, through detailed analysis of steady state, transient behavior. Polymerization, combustion, solids processing, environmental modeling. Design of multiphase reactors. Undergraduate version of 8501.

CHEN 5221 **- Introduction to Polymer Chemistry** Fall
(3.0 cr; =[CHEM 4221, CHEM 8221, MATS 5221, MATS 8221]; Prereq-[Chem 2302, Chem 3501] or #; A-F or Aud)
Condensation, radical, ionic, emulsion, ring-opening, metal-catalyzed polymerizations. Chain conformation, solution thermodynamics, molecular weight characterization, physical properties.
Can register in MatS 5221.

CHEM 4011 **- Mechanisms of Chemical Reactions** Fall
(3.0 cr; Prereq-[2302, 3501] or equiv; fall, every year)

Reaction mechanisms, methods of study. Mechanistic concepts. Gas phase reactions. "Electron pushing" mechanisms in organic/enzymatic reactions. Kinetic schemes, other strategies.

CHEM 4021 **- Computational Chemistry** Spring
(3.0 cr; Prereq-3502 or equiv; spring, every year)
Theoretical methods for study of molecular structure, bonding, and reactivity. Ab initio and semi-empirical calculations of molecular electronic structure. Theoretical determination of molecular electronic structure and spectra; relation to experimental techniques. Molecular mechanics. Structure determination for large systems. Molecular properties and reactivity. Computational tools. Critical assessment of methods and theoretical work in the literature. Lab.

CHEM 4201 **- Materials Chemistry** Fall
(3.0 cr; =[CHEM 8201]; Prereq-[[3502 or equiv], 4701] or #; fall, every year)
Crystal systems/unit cells, phase diagrams, defects/interfaces, optical/ dielectric properties, electrical/thermal conductivity, X-ray diffraction, thin film analysis, electronic structure, polarons/phonons, solid state chemistry, liquid/molecular crystals, polymers, magnetic/optical materials, porous materials, ceramics, piezoelectric materials, biomedical materials, catalysts.

CHEM 4223W **- Polymer Laboratory (WI)** Spring
(2.0 cr; =[MATS 5223W]; Prereq-4221 or 8221 or MATS 5221 or CHEN 4214 or CHEN 5221 or #; spring, every year)
Synthesis, characterization, and physical properties of polymers. Free radical, condensation, emulsion, anionic polymerization. Infrared spectroscopy/gel permeation chromatography. Viscoelasticity, rubber elasticity, crystallization.

CHEM 4311W **- Advanced Organic Chemistry Lab (WI)** Fall, Spring
(2.0 cr; Prereq-2311; fall, spring, every year)
Reactions, techniques, and instrumental methods in synthetic organic chemistry.

CHEM 4321 **- Organic Synthesis** Fall
(3.0 cr; Prereq-[2302 or equiv], 3501, #; fall, every year)
Fundamental concepts, reactions, reagents, structural/stereochemical issues, mechanistic skills for organic chemistry.

CHEM 4322 **- Advanced Organic Chemistry** Spring
(3.0 cr; Prereq-[2302 or equiv], 3501, #; spring, every year)
Topics vary by instructor. Examples: natural products, heterocycles, asymmetric synthesis, organometallic chemistry, polymer chemistry.

CHEM 4411 **- Introduction to Chemical Biology** Fall
(3.0 cr; Prereq-[2302 or equiv], 3501; fall, every year)
Chemistry of amino acids, peptides, proteins, lipids, carbohydrates, and nucleic acids. Structure, nomenclature, synthesis, and reactivity. Techniques to characterize biomolecules.

CHEM 4413 **- Nucleic Acids** Spring, offered when feasible
(3.0 cr; Prereq-2302, [3501 or equiv]; spring, offered when feasible)
Chemistry/biology of nucleic acids. Structure, thermodynamics, reactivity, DNA repair, chemical oligonucleotide synthesis, antisense approaches, ribozymes. Techniques for nucleic acid research. Interactions with small molecules/proteins.

CHEM 4511W **- Advanced Physical Chemistry Lab (WI)** Fall
(2.0 cr; Prereq-3501-3502, chemistry major; fall, every year)
Experiments illustrating principles and methods of thermodynamics, reaction kinetics, and quantum mechanics.

CHEM 4701 **- Inorganic Chemistry** Fall
(3.0 cr; Prereq-2311, [3501 or & 3501 or 3502 or & 3502]; fall, every year)
Advanced introduction to inorganic chemistry. Periodic trends. Structure and bonding concepts in compounds where s and p electrons are important. Descriptive chemistry of solids and transition metal compounds. Emphasizes transition metal chemistry. Advanced topics in main group and materials chemistry.

CHEM 4711W **- Advanced Inorganic Chemistry Lab (WI)** Spring
(2.0 cr; Prereq-4701, chem major; A-F or Aud, spring, every year)
Lab experiments in inorganic/organometallic chemistry illustrating synthetic/spectroscopic techniques.

CHEM 4725 **- Organometallic Chemistry** Fall, offered when feasible
(3.0 cr; Prereq-4701 or equiv, chem major or #; fall, offered when feasible)
Synthesis, reactions, structures, and other properties of main group and transition metal organometallic compounds; electronic and structural theory, emphasizing their use as stoichiometric and homogeneous catalytic reagents in organic and inorganic systems.

CHEM 4745 **- Advanced Inorganic Chemistry** Spring, offered when feasible
(3.0 cr; Prereq-4701, chem major, #; spring, offered when feasible)
Topics in main group and transition metal chemistry. Emphasizes synthesis, structure, physical properties, and chemical reactivity.

CHEM 5210 **- Materials Characterization** Spring
(4.0 cr; Prereq-grad student or #; A-F or Aud, spring, every year)
Modern tools/techniques for both bulk- and thin-film characterization. Topics may include ion-solid interactions, Rutherford back scattering, secondary ion mass spectrometry, solid-state NMR, x-ray photoelectron spectroscopy, small-angle x-ray/neutron scattering, transmission/scanning electron/probe microscopy, near-field scanning optical microscopy, porosimetry, adsorption techniques, and ellipsometry.

MATS 4212 **- Ceramics** Fall
(3.0 cr; Prereq-[3011, [MatS or ChEn] sr] or #; fall, every year)
Structure of ceramics: crystal structures, non-crystalline (glass) structures, microstructure. Ceramic phase relationships: binary/ternary diagrams. Ceramic properties: thermal, mechanical, electrical, magnetic, optical. Computer applications.

MATS 4511W **- Corrosion and Electrochemistry of Corrosion (WI)** Fall, Spring, offered when feasible
(4.0 cr; Prereq-MatS 3011 or #, upper div IT or grad; fall, spring, offered when feasible)
Electrochemical thermodynamics, electrochemical kinetics, theory of aqueous corrosion, theory of high temperature oxidation; specific topics include general corrosion, passivation, pitting, galvanic protection/corrosion, environmental degradation of mechanical properties, corrosion of electronic components, growth of oxide scales by diffusion, materials selection and design. Computers used to collect lab data.

Computational/Numerical Analysis – Derby or Daoutidis or Kumar

You must take into consideration the five points on page 9.

CSCI 5304 **- Computational Aspects of Matrix Theory** Fall
(3.0 cr; Prereq-2031 or #; fall, every year)
Perturbation theory for linear systems and eigenvalue problems. Direct/iterative solution of large linear systems. Matrix factorizations. Computation of eigenvalues/eigenvectors. Singular value decomposition. LAPACK/other software packages. Introduction to sparse matrix methods.

CSCI 5451 **- Introduction to Parallel Computing: Architectures, Algorithms, and Programming** Spring
(3.0 cr; Prereq-4041 or #; spring, every year)
Parallel architectures design, embeddings, routing. Examples of parallel computers. Fundamental communication operations. Performance metrics. Parallel algorithms for sorting. Matrix problems, graph problems, dynamic load balancing, types of parallelisms. Parallel programming paradigms. Message passing programming in MPI. Shared-address space programming in openMP or threads.

MATH 5485 **- Introduction to Numerical Methods I** Fall
(4.0 cr; Prereq-[2243 or 2373 or 2573], familiarity with some programming language; fall, every year)
Solution of nonlinear equations in one variable. Interpolation, polynomial approximation, numerical integration/differentiation, numerical solution of initial-value problems.

MATH 5486 **- Introduction To Numerical Methods II** Spring
(4.0 cr; Prereq-5485; spring, every year)
Direct/iterative methods for solving linear systems, approximation theory, methods for eigenvalue problems, methods for systems of nonlinear equations, numerical solution of boundary value problems for ordinary differential equations.

Drug Delivery Design and Evaluation - McCormick or Prof. Cheryl Zimmerman in the Pharmaceutics Department

You must take into consideration the five points on page 9.

BIOC 4521 **- Introduction to Physical Biochemistry** Fall, Spring
(3.0 cr; Prereq-CHEM 1022, MATH 1272, PHYS 1202; 4331 recommended; fall, spring, every year)
Physical chemical principles, their applications in biochemistry. Thermodynamics, kinetics, spectroscopy, and solution dynamics as applied to biochemical reactions and biopolymers.

BIOC 5527 **- Introduction to Modern Structural Biology** Fall
(4.0 cr; Prereq-[intro biochemistry, intro physics] or physical chemistry or #; fall, every year)
Methods employed in modern structural biology to elucidate macromolecular structures. Primary focus on X-ray diffraction, nuclear magnetic resonance (NMR) spectroscopy and mass spectrometry. Principles underlying structural biology and structure/function relationships.

BMEN 5001 **- Advanced Biomaterials** Fall
(3.0 cr; Prereq-3301 or MatS 3011 or grad student or #; A-F or Aud, fall, every year)
Commonly used biomaterials. Chemical/physical aspects. Practical examples from such areas as cardiovascular/orthopedic applications, drug delivery, and cell encapsulation. Methods used for chemical analysis and for physical characterization of biomaterials. Effect of additives, stabilizers, processing conditions, and sterilization methods.

BMEN 5311 **- Advanced Biomedical Transport Processes** Spring
(3.0 - 4.0 cr [max 4.0 cr]; =[CHEN 5753, ME 5381]; Prereq-IT upper div or grad student or #; [ChEn 5103 or ME 5342] recommended; spring, every year)
Introduction to biological fluid, mass, and heat transport. Mass transfer across membranes. Fluid flow in vessels/interstitium. Heat transfer in cells, tissues, and body. Applications to blood oxygenation, respiration, drug delivery, and tissue engineering.

CHEN 5759 **- Principles of Mass Transfer in Engineering and Biological Engineering** Fall
(2.0 cr; Prereq-4002; A-F or Aud, fall, every year)
Principles of mass transfer in gases, liquids, biological and macromolecular solutions, gels, solids, membranes, and capillaries. Porous solids interaction between mass transfer and chemical reaction. Applications in biological, environmental, mineral, and chemical engineering systems.

PHAR 6163 **- Pharmacokinetics** Fall
(3.0 cr; Prereq-Calculus II (quarter), calculus I (semester) or equiv, 6162; A-F or Aud, fall, every year)
Physiological basis for drug absorption, distribution, metabolism and excretion; use of mathematical principles and equations to describe these processes as well as design dosage regimens for individual patients.

PHAR 6164 **- Biopharmaceutics** Fall
(3.0 cr; Prereq-6163, & 6175; A-F or Aud, fall, every year)
Applied theory of dosage form design for optimal drug activity and bioavailability for all routes of drug administration.

PHAR 6224 **- Pharmacogenomics: Genetic Basis for Variability in Drug Response** Spring, every year
(2.0 cr; Prereq-2nd or 3rd yr pharmacy; A-F or Aud, spring, every year)
Theory/practice of pharmacogenomics. Principles of human genetics/genomics. Applications to scientific education, problems in drug therapy optimization, and patient care.

PHCL 5110 **- Introduction to Pharmacology** Fall
(3.0 cr; Prereq-Grad student or #; A-F or Aud, fall, every year)
Basic principles of Pharmacology. Focuses on molecular mechanisms of drug action.

PHSL 5061 **- Principles of Physiology for Biomedical Engineering** Fall
(4.0 cr; Prereq-Biomedical engineering grad, one yr college chem and physics and math through integral calculus; fall, every year)
Human physiology with emphasis on quantitative aspects. Organ systems (circulation, respiration, renal, gastrointestinal, endocrine, muscle, central and peripheral nervous systems), cellular transport processes, and scaling in biology.

Environmental Engineering – Cussler

You must take into consideration the five points on page 9.

NOTE! CE 3501 Environmental Engineering is not approved as a ChEn emphasis elective.

CE 4502 **- Water and Wastewater Treatment** Fall, Spring
(3.0 cr; Prereq-3501; A-F or Aud, fall, spring, every year)
Theory of chemical, physical, and biological processes in treating water and wastewater. Sequencing of processes. Design of treatment facilities.

CE 4561 **- Solid Hazardous Wastes** Fall, Spring
(3.0 cr; Prereq-IT or grad, Chem 1022, 3501 or #; fall, spring, every year)
Solid and hazardous waste characterization; regulatory legislation; waste minimization; resource recovery; chemical, physical, and biological treatment; thermal processes; disposal practices. Analysis and design of systems for treatment and disposal.

CE 4562 **- Environmental Remediation Technology** Spring
(3.0 cr; Prereq-[3501, 4501] or #; A-F or Aud, spring, every year)
Technologies designed for removal of pollutants from groundwater and soils. Advances in technological design. Emerging technologies such as in situ bioremediation, phytoremediation. Role of environmental biotechnology in pollution abatement.

CHEN 5551 **- Survey of Renewable Energy Technologies** Fall
(3.0 cr; Prereq-[Upper div or #], basic knowledge of chemistry, thermodynamics; A-F or Aud, fall, every year)
Technologies to generate renewable energy/chemicals. Biomass, solar, wind, hydroelectric. Emphasizes biomass processing using chemical/biological methods. Renewable technologies compared with fossil fuel technologies.

CHEN 5751 **- Biochemical Engineering** Spring
(3.0 cr; Prereq-4002, & 4003, & 4102; A-F or Aud, spring, every year)
Chemical engineering principles applied to analysis/design of complex cellular/enzyme processes. Quantitative framework for design of cells for production of proteins, synthesis of antibodies with mammalian cells, or degradation of toxic compounds in contaminated soil.

ME 5115 **- Air Quality and Air Pollution Control**
(4.0 cr; Prereq-IT upper div or grad student; A-F or Aud)
Air pollution sources, atmospheric transport, transformations, fate, and emissions control. Air pollution meteorology, dispersion, chemistry of secondary pollutant formation, standards and regulation. Control devices and techniques for gaseous and particulate emissions. Cyclones, electrostatic precipitators, wet and dry scrubbers, combustion modification.

Food Engineering – Hu

You must take into consideration the five points on page 9.

BBE 4723 **- Food Process Engineering** Spring, odd years
(3.0 cr; Prereq-[4013 or &4013], upper div IT; A-F or Aud, spring, odd years)
Application of principles of heat transfer and fluid flow to design of food processing operations such as thermal/aseptic processing, freezing, pumping, drying, evaporation, extrusion. Marketing, government regulation, nutrition issues.

CHEN 5751 **- Biochemical Engineering** Spring
(3.0 cr; Prereq-4002, & 4003, & 4102; A-F or Aud, spring, every year)
Chemical engineering principles applied to analysis/design of complex cellular/enzyme processes. Quantitative framework for design of cells for production of proteins, synthesis of antibodies with mammalian cells, or degradation of toxic compounds in contaminated soil.

FSCN 4111 **- Food Chemistry** Fall
(3.0 cr; Prereq-3102, BioC 3021; fall, every year)
Study of chemical structures and functional properties of food components in relation to their roles as parts of complex biochemical systems and as modified by environmental and processing factors.

FSCN 5441 **- Introduction to New Product Development** Spring, even years
(2.0 cr; Prereq-4111, 4331; fall, spring, even years)
Interactive course that introduces students to the principles of new product development, from identification and testing of new product concepts, through prototype testing, to basic process design using examples from industry.

General Chemical Engineering – McCormick

You must take into consideration the five points on page 9.

This area is a selection of courses and experiences meant to best prepare you for a wide range of chemical engineering jobs and for graduate study. You may take ANY course listed with ANY emphasis area. In addition, the following courses are especially recommended.

CHEN 4214 **- Polymers** (preferred) Spring
(3.0 cr; Prereq-Grade of at least C in MatS 3011, ChEn major upper division or #; spring, every year)
Polymer structure-property relations: structure/morphology of crystalline/amorphous states. Crystallization kinetics. Vitrification and the glass transition. Mechanical properties, failure, permeability, optical/electrical properties, polymer composites, effect of processing on properties.

CHEN 4701 **- Advanced Undergraduate Applied Math I: Linear Analysis** Fall
(3.0 cr; =[CHEN 8201]; Prereq-4102, ChEn major upper division; A-F or Aud, fall, every year)
Integrated approach to solving linear mathematical problems (linear algebraic equations, linear ordinary/partial differential equations) using theoretical/numerical analysis based on linear operator theory. Undergraduate version of 8201.

CHEN 4702 **- Advanced Undergraduate Rheology** Spring
(2.0 cr; Prereq-4002 or 4005, #; A-F or Aud, spring, every year)
Deformation/flow of non-Newtonian/viscoelastic fluids, plastic materials, perfectly elastic solids. Phenomenological/molecular interpretation of rheology of elastomers, polymer melts, polymer solutions. Application of rheology to polymer processing. Undergraduate version of 8102.

CHEN 4703 **- Advanced Undergraduate Applied Math II: Nonlinear Analysis** Spring
(3.0 cr; Prereq-ChEn 4002, ChEn major upper division; grad-level course in linear analysis recommended; A-F or Aud, spring, every year)
Nonlinear mathematical problems (nonlinear ordinary/partial differential equations) using theoretical/numerical analysis. Undergraduate version of 8202.

CHEN 4704 **- Advanced Undergraduate Physical Rate Processes I: Transport** Fall, Spring
(3.0 cr; Prereq-4005, ChEn major upper div; A-F or Aud, fall, spring, every year)
Mass transfer, dilute/concentrated diffusion, Brownian motion. Diffusion coefficients in polymers, of electrolytes, at critical points. Multicomponent diffusion. Correlations/predictions. Mass transfer, chemical reaction.

CHEN 4706 **- Advanced Undergraduate Physical and Chemical Thermodynamics** Fall, Spring
(3.0 cr; Prereq-CHEM 3502, 4101, 4005, ChEn major upper div; background in undergrad engineering or chemistry courses in thermodynamics recommended; A-F or Aud, fall, spring, every year)
Principles of classical thermodynamics, introduction to nonequilibrium thermodynamics. Applications in chemical engineering, materials science.

CHEN 4707 **- Advanced Undergraduate Statistical Thermodynamics and Kinetics** Fall
(3.0 cr; Prereq-4005, 4101, CHEM 3501, CHEM 3502, ChEn major upper div; A-F or Aud, fall, every year)
Introduction to statistical mechanical description of equilibrium/non-equilibrium properties of matter. Emphasizes fluids, classical

statistical mechanics.

CHEN 4708 **- Advanced Undergraduate Chemical Rate Processes: Analysis of Chemical Reactors** Spring
(3.0 cr; Prereq-4102, ChEn major upper division; A-F or Aud, spring, every year)
Design of reactors for heat management, with catalytic processes, through detailed analysis of steady state, transient behavior. Polymerization, combustion, solids processing, environmental modeling. Design of multiphase reactors. Undergraduate version of 8501.

CHEN 5221 **- Introduction to Polymer Chemistry** Fall
(3.0 cr; =[CHEM 4221, CHEM 8221, MATS 5221, MATS 8221]; Prereq-[Chem 2302, Chem 3501] or #; A-F or Aud)
Condensation, radical, ionic, emulsion, ring-opening, metal-catalyzed polymerizations. Chain conformation, solution thermodynamics, molecular weight characterization, physical properties.
Can register in MatS 5221.

CHEN 5531 **- Electrochemical Engineering & Renewable Energy**
(3.0 cr; =[MATS 5531]; Prereq-[MatS 3011 or #], [upper div IT or grad student])
Fundamentals of electrochemical engineering. Electrochemical mass transfer electrokinetics, thermodynamics of electrochemical cells, modern sensors. Formation of thin films and microstructured materials. Computer-based problems.

CHEN 5551 **- Survey of Renewable Energy Technologies** Fall
(3.0 cr; Prereq-[Upper div or #], basic knowledge of chemistry, thermodynamics; A-F or Aud, fall, every year)
Technologies to generate renewable energy/chemicals. Biomass, solar, wind, hydroelectric. Emphasizes biomass processing using chemical/biological methods. Renewable technologies compared with fossil fuel technologies.

CHEN 5751 **- Biochemical Engineering** Spring
(3.0 cr; Prereq-4002, & 4003, & 4102; A-F or Aud, spring, every year)
Chemical engineering principles applied to analysis/design of complex cellular/enzyme processes. Quantitative framework for design of cells for production of proteins, synthesis of antibodies with mammalian cells, or degradation of toxic compounds in contaminated soil.

CHEN 5752 **- Quantitative Biology for Engineers**
(3.0 cr; =[CHEN 8752]; Prereq-Engineering background, #; A-F or Aud)
Biological fundamentals of biotechnology. Structural basis of biological systems. Communication between cells/environment. Gene expression. Proteins and their functional classes. Metabolic pathways and their reactions. From gene/genome to physiology. Genomics/proteomics as technologies. Biotechnology and society: ethics, law, public policy. Biotechnology-based commercial enterprises.

CHEN 5771 **- Colloids and Dispersions** Fall
(3.0 cr; =[01472]; Prereq-Physical chemistry; A-F or Aud, fall, every year)
Preparation, stability, coagulation kinetics or colloidal solutions. DLVO theory, electrokinetic phenomena. Properties of micelles, other microstructures.

MATS 4212 **- Ceramics** Fall
(3.0 cr; Prereq-[3011, [MatS or ChEn] sr] or #; fall, every year)
Structure of ceramics: crystal structures, non-crystalline (glass) structures, microstructure. Ceramic phase relationships: binary/ternary diagrams. Ceramic properties: thermal, mechanical, electrical, magnetic, optical. Computer applications.

ME 5113 **- Aerosol/Particle Engineering** Fall
(4.0 cr; Prereq-IT upper div or grad student; A-F or Aud, fall, every year)
Kinetic theory, definition, theory and measurement of particle properties, elementary particle mechanics, particle statistics; Brownian motion and diffusion, coagulation, evaporation and condensation, sampling and transport.

Industrial Engineering – Caretta

You must take into consideration the five points on page 9.

EE 3015 **- Signals and Systems** Fall, Spring
(3.0 cr; Prereq-[2011, IT] or %; fall, spring, every year)
Basic techniques for analysis/design of signal processing, communications, and control systems. Time/frequency models, Fourier-domain representations, modulation. Discrete-time/digital signal/system analysis. Z transform. State models, stability, feedback.

EE 4231 **- Linear Control Systems: Designed by Input/Output Methods** Fall
(3.0 cr; Prereq-[3015, [upper div IT or grad student in IT major]] or #; no [EE or CompE] grad cr; fall, every year)
Modeling, characteristics, and performance of feedback control systems. Stability, root locus, and frequency response methods. Digital implementation, hardware considerations.

IE 4521 **- Statistics, Quality, and Reliability** Fall, Spring, Summer
(4.0 cr; Prereq-Upper div or grad student or CNR; fall, spring, summer, every year)
Random variables/probability distributions, statistical sampling/measurement, statistical inferencing, confidence intervals, hypothesis testing, single/multivariate regression, design of experiments, statistical quality control, quality management, reliability, maintainability, availability.

IE 5441 **- Engineering Cost Accounting and Cost Control** Fall, Spring, Summer
(4.0 cr; A-F or Aud, fall, spring, summer, every year)
Financial accounting, managerial accounting, engineering economics. Preparing financial statements, handling accounts payable/receivable, inventories, depreciation. Financing sources, capital cost/structure. Time value of money and of risk in managerial decision making. Design of cost accounting system and activity-based accounting.

IE 5522 **- Quality Engineering and Reliability** Fall, Spring, offered when feasible
(4.0 cr; Prereq-[4521 or equiv], [upper div or grad student or CNR]; fall, spring, offered when feasible)
Quality engineering/management, economics of quality, statistical process control design of experiments, reliability, maintainability, availability.

IE 5513 **- Engineering Safety** Fall, Spring
(4.0 cr; Prereq-Upper div IT or grad student; A-F or Aud, fall, spring, every year)
Occupational, health, and product safety. Standards, laws, and regulations. Hazards and their engineering control, including general principles, tools and machines, mechanics and structures, electrical safety, materials handling, fire safety, and chemicals. Human behavior and safety, procedures and training, warnings and instructions.

ME 5223 **- Materials in Design** Fall
(4.0 cr; Prereq-3221; fall, every year)
Fundamental properties of engineering materials. Fabrication, treatment. Physical and corrosive properties. Failure mechanism, cost and value analysis as related to material selection and specification.

Materials Science – Francis

You must take into consideration the five points on page 9.

CHEM 4223W **- Polymer Laboratory (WI)** Spring
(2.0 cr; =[MATS 5223W]; Prereq-4221 or 8221 or MATS 5221 or CHEN 4214 or CHEN 5221 or #; spring, every year)
Synthesis, characterization, and physical properties of polymers. Free radical, condensation, emulsion, anionic polymerization. Infrared spectroscopy/gel permeation chromatography. Viscoelasticity, rubber elasticity, crystallization.

CHEN 4214 **- Polymers** (preferred) Spring
(3.0 cr; Prereq-Grade of at least C in MatS 3011, ChEn major upper division or #; spring, every year)
Polymer structure-property relations: structure/morphology of crystalline/amorphous states. Crystallization kinetics. Vitrification and the glass transition. Mechanical properties, failure, permeability, optical/electrical properties, polymer composites, effect of processing on properties.

MATS 4013 **- Electrical and Magnetic Properties of Materials** Fall
(3.0 cr; Prereq-[3011, upper div [MatS or ChEn]] or #; A-F or Aud, fall, every year)
Electronic/magnetic properties of solids. Simple band theory of solids. Free electron theory of conductivity/transport. Optical/dielectric response functions. Elementary theory of magnetism. Electronic devices. Superconductivity. Computer-based problems to illustrate applications.

MATS 4212 **- Ceramics** Fall
(3.0 cr; Prereq-[3011, [MatS or ChEn] sr] or #; fall, every year)
Structure of ceramics: crystal structures, non-crystalline (glass) structures, microstructure. Ceramic phase relationships: binary/ternary diagrams. Ceramic properties: thermal, mechanical, electrical, magnetic, optical. Computer applications.

MATS 4301W **- Materials Processing (WI)** Spring
(4.0 cr; Prereq-MatS 4212 and 4214; spring, every year)
Casting, solidification and plastic forming of metals; powder processing, forming operations, sintering of ceramics; and processing of thermoplastic and thermoset polymers. Computer applications of data collection and reduction. Additional laboratory projects available to graduate students.

MATS 4511W **- Corrosion and Electrochemistry of Corrosion (WI)** Fall, Spring, offered when feasible
(4.0 cr; Prereq-MatS 3011 or #, upper div IT or grad; fall, spring, offered when feasible)
Electrochemical thermodynamics, electrochemical kinetics, theory of aqueous corrosion, theory of high temperature oxidation; specific topics include general corrosion, passivation, pitting, galvanic protection/corrosion, environmental degradation of mechanical properties, corrosion of electronic components, growth of oxide scales by diffusion, materials selection and design. Computers used to collect lab data.

MATS 5531 **- Electrochemical Engineering** Fall
(3.0 cr; =[CHEN 5531]; Prereq-MatS 3011 or #, upper div IT or grad; fall, offered when feasible)
Fundamentals of electrochemical engineering. Topics include electrochemical mass transfer electrokinetics, thermodynamics of cells, modern sensors, formation of thin films and microstructured materials. Computer-based problems will be assigned.

Mathematics and Statistics – Daoutidis or Kumar

You must take into consideration the five points on page 9.

MATH 2283 **- Sequences, Series, and Foundations** Fall, Spring
(3.0 cr; =[MATH 3283W]; Prereq-& [2243 or 2263 or 2373 or 2374]; fall, spring, every year)
Introduction to mathematical reasoning used in advanced mathematics. Elements of logic. Mathematical induction. Real number system. General, monotone, recursively defined sequences. Convergence of infinite series/sequences. Taylor's series. Power series with applications to differential equations. Newton's method.

MATH 4457 **- Methods of Applied Mathematics I** Fall
(4.0 cr; =[MATH 4242]; Prereq-[2243 or 2373 or 2573], [2263 or 2374 or 2574]; fall, every year)
Vector spaces, minimization principles, least squares approximation, orthogonal bases, linear functions, linear systems of ordinary differential equations. Applications include statics/dynamics of electrical circuits, mechanical structures. Stability/resonance, approximation/interpolation of data. Numerical methods and geometry.

MATH 4458 **- Methods of Applied Mathematics II** Spring
(4.0 cr; Prereq-4457; spring, offered when feasible)
Boundary value problems, partial differential equations, complex variables, dynamical systems, calculus of variations, numerical methods. Green's functions, delta functions, Fourier series/integrals, wavelets, conformal mapping, finite elements/differences. Applications: fluid/continuum mechanics, heat flow, signal processing, quantum mechanics.

MATH 4567 **- Applied Fourier Analysis** Fall, Spring
(4.0 cr; Prereq-2243 or 2373 or 2573; fall, spring, every year)
Fourier series, integral/transform. Convergence. Fourier series, transform in complex form. Solution of wave, heat, Laplace equations by separation of variables. Sturm-Liouville systems, finite Fourier, fast Fourier transform. Applications. Other topics as time permits.

MATH 5445 **- Mathematical Analysis of Biological Networks** Spring
(4.0 cr; Prereq-Linear algebra, differential equations; spring, every year)
Development/analysis of models for complex biological networks. Examples taken from signal transduction networks, metabolic networks, gene control networks, and ecological networks.

Microelectronic materials – Caretta or Aydil

You must take into consideration the five points on page 9.

EE 3161 **- Semiconductor Devices** Fall, Spring
(3.0 cr; Prereq-Upper div IT, 2011, Phys 1302, Phys 2303 or Chem 1022; fall, spring, every year)
Elementary semiconductor physics; physical description of pn junction diodes, bipolar junction transistors, field-effect transistors.

EE 5171 **- Microelectronic Fabrication** Fall
(4.0 cr; Prereq-IT grad student or %; fall, every year)
Fabrication of microelectronic devices. Silicon integrated circuits, GaAs devices. Lithography, oxidation, diffusion. Process integration of various technologies, including CMOS, double poly bipolar, and GaAs MESFET.

EE 5173 **- Basic Microelectronics Laboratory** Fall
(1.0 cr; Prereq-[[5171 or &5171], IT grad student] or %; fall, every year)
Students fabricate a polysilicon gate, single-layer metal, NMOS chip, performing 80 percent of processing, including photolithography, diffusion, oxidation, and etching. In-process measurement results are compared with final electrical test results. Simple circuits are used to estimate technology performance.

EE 5653 **- Physical Principles of Magnetic Materials** Fall
(3.0 cr; Prereq-IT grad student or %; fall, every year)
Physics of diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism. Ferromagnetic phenomena. Static/dynamic theory of micromagnetics, magneto-optics, and magnetization dynamics. Magnetic material applications.

EE 5655 **- Magnetic Recording** Spring, offered when feasible
(3.0 cr; Prereq-IT grad student or %; spring, offered when feasible)
Magnetic fundamentals, recording materials, idealized models of magnetic records/reproduction, analytic models of magnetic record heads, sinusoidal magnetic recording, digital magnetic recording, magnetic recording heads/media, digital recording systems.

Polymers – Macosko

You must take into consideration the five points on page 9.

CHEM 4223W **- Polymer Laboratory (WI)** Spring
(2.0 cr; =[MATS 5223W]; Prereq-4221 or 8221 or MATS 5221 or CHEN 4214 or CHEN 5221 or #; spring, every year)
Synthesis, characterization, and physical properties of polymers. Free radical, condensation, emulsion, anionic polymerization. Infrared spectroscopy/gel permeation chromatography. Viscoelasticity, rubber elasticity, crystallization.

CHEN 4214 **- Polymers** (preferred) Spring
(3.0 cr; Prereq-Grade of at least C in MatS 3011, ChEn major upper division or #; spring, every year)
Polymer structure-property relations: structure/morphology of crystalline/amorphous states. Crystallization kinetics. Vitrification and the glass transition. Mechanical properties, failure, permeability, optical/electrical properties, polymer composites, effect of processing on properties.

CHEN 4702 **- Advanced Undergraduate Rheology** Spring
(2.0 cr; Prereq-4002 or 4005, #; A-F or Aud, spring, every year)
Deformation/flow of non-Newtonian/viscoelastic fluids, plastic materials, perfectly elastic solids. Phenomenological/molecular interpretation of rheology of elastomers, polymer melts, polymer solutions. Application of rheology to polymer processing. Undergraduate version of 8102.

CHEN 5221 **- Introduction to Polymer Chemistry** Fall
(3.0 cr; =[CHEM 4221, CHEM 8221, MATS 5221, MATS 8221]; Prereq-[Chem 2302, Chem 3501] or #; A-F or Aud)
Condensation, radical, ionic, emulsion, ring-opening, metal-catalyzed polymerizations. Chain conformation, solution thermodynamics, molecular weight characterization, physical properties.
Can register in MatS 5221.

CHEN 5771 **- Colloids and Dispersions** Fall
(3.0 cr; =[01472]; Prereq-Physical chemistry; A-F or Aud, fall, every year)
Preparation, stability, coagulation kinetics or colloidal solutions. DLVO theory, electrokinetic phenomena. Properties of micelles, other microstructures.

PHYS 4911 **- Introduction to Biopolymer Physics** Spring
(3.0 cr; =[PHYS 5081]; Prereq-[2303, 2403H, 2503] or Chem 3501 or #; spring, every year)
Introduction to biological and soft condensed matter physics. Emphasizes physical ideas necessary to understand behavior of macromolecules and other biological materials. Elements of thermodynamics and statistical mechanics are presented as needed.

Pre-medical – Tranquillo

You must take into consideration the five points on page 9.

NOTE: Some credits from Biol 2xxx and 3xxx e.g. [BIOL 2005, 3211 and BIOC 3021] below can be approved if required for Medical School applications. Must petition Professor Tranquillo.

[BIOL 2005 **- Animal Diversity Laboratory**] Fall, Spring, Summer
(1.0 cr; =[BIOL 2012]; fall, spring, summer, every year)
Dissection, direct observation of representatives of major animal groups.

[BIOL 3211 **- Animal Physiology**] Fall, Spring, Summer
(3.0 cr; Prereq-[1002 or 1009], Chem 1021; & 2005 strongly recommended; fall, spring, summer, every year)
Compares ways different animals solve similar physiological problems.

[BIOC 3021 **- Biochemistry**] Fall, Spring, Summer
(3.0 cr; =[BIOC 6021]; Prereq-[Biol 1002 or 1009], Chem 2301; fall, spring, summer, every year)
Fundamentals of biochemistry including structure and function of proteins, nucleic acids, lipids and carbohydrates; metabolism and regulation of metabolism; quantitative treatments of chemical equilibria, enzyme catalysis and bioenergetics; the chemical basis of genetic information flow.

Prof. Tranquillo will also approve 4xxx or higher level courses in the life sciences or bioengineering, preferably biomedical engineering. He recommends that you also contact the Health Careers Center to enroll in the "First Step" program for pre-med students.

Health Careers Center
Website: www.healthcareers.umn.edu
Email: Health.Careers.Center@umn.edu
Phone: (612) 624-6767 Fax: (612) 624-4415
2-565 Moos Tower
Open Monday through Friday from 8:00 a.m. to 4:30 p.m. and closed on University holidays.

Renewable and Process Chemistry – Schmidt

You must take into consideration the five points on page 9.

Prof. Schmidt can approve other courses by petition, sometimes with only partial technical elective credit.

Note: See Prof. McCormick and Prof. Tschirner if interested in BBE minor and further BBE courses.

BBE 4301 **- Surface and Colloid Science in Bio-based Products Manufacturing** Spring
(3.0 cr; =[BBE 5301]; Prereq-Chem 3501, [jr or sr or #]; spring, every year)
Principles of surface/colloid science, their application to understanding manufacturing/performance of bio-based products.

BBE 4733 **- Renewable Energy Technologies** Spring
(3.0 cr; Prereq-4013 or equiv or #; A-F or Aud, spring, every year)
Fundamentals of current/emerging technologies for renewable energy production/use. Issues regarding national energy security. Environmental, economic, and societal impacts of renewable energy. Current/future developments in renewable energy technologies. Impact of renewable energy on sustainable development.

CHEM 4001 **- Chemistry of Plant Materials** Fall
(4.0 cr; =[01147]; Prereq-2302, [jr or sr or #]; A-F or Aud, fall, every year)
Chemical principles underlying structure, properties, processing, and performance of plant materials.

CHEM 4066 **- Chemistry of Industry** Spring
(3.0 cr; Prereq-Chem sr or grad student or #; spring, every year)
Industrial and polymer chemistry technology. Relation of basic properties to industrial utility. Economics, social problems, industrial environment.

CHEM 4301 **- Surface and Colloid Science in Bio-based Products Manufacturing** Spring
(3.0 cr; =[01193]; Prereq-3501, [jr or sr or #]; spring, every year)
Principles of surface/colloid science, their application to understanding manufacturing/performance of bio-based products.

CHEN 4708 **- Advanced Undergraduate Chemical Rate Processes: Analysis of Chemical Reactors** Spring
(3.0 cr; Prereq-4102, ChEn major upper division; A-F or Aud, spring, every year)
Design of reactors for heat management, with catalytic processes, through detailed analysis of steady state, transient behavior. Polymerization, combustion, solids processing, environmental modeling. Design of multiphase reactors. Undergraduate version of 8501.

CHEN 5221 **- Introduction to Polymer Chemistry** Fall
(3.0 cr; =[CHEM 4221, CHEM 8221, MATS 5221, MATS 8221]; Prereq-[Chem 2302, Chem 3501] or #; A-F or Aud)
Condensation, radical, ionic, emulsion, ring-opening, metal-catalyzed polymerizations. Chain conformation, solution thermodynamics, molecular weight characterization, physical properties.
Can register in MatS 5221.

CHEN 5531 **- Electrochemical Engineering**
(3.0 cr; =[MATS 5531]; Prereq-[MatS 3011 or #], [upper div IT or grad student])
Fundamentals of electrochemical engineering. Electrochemical mass transfer electrokinetics, thermodynamics of electrochemical cells, modern sensors. Formation of thin films and microstructured materials. Computer-based problems.

CHEN 5551 **- Survey of Renewable Energy Technologies** Fall
(3.0 cr; Prereq-[Upper div or #], basic knowledge of chemistry, thermodynamics; A-F or Aud, fall, every year)
Technologies to generate renewable energy/chemicals. Biomass, solar, wind, hydroelectric. Emphasizes biomass processing using chemical/biological methods. Renewable technologies compared with fossil fuel technologies.

MATS 4511W **- Corrosion and Electrochemistry of Corrosion (WI)** Spring, offered when feasible
(4.0 cr; Prereq-MatS 3011 or #, upper div IT or grad; fall, spring, offered when feasible)
Electrochemical thermodynamics, electrochemical kinetics, theory of aqueous corrosion, theory of high temperature oxidation; specific topics include general corrosion, passivation, pitting, galvanic protection/corrosion, environmental degradation of mechanical properties, corrosion of electronic components, growth of oxide scales by diffusion, materials selection and design. Computers used to collect lab data.

ME 4431W **- Energy Conversion Systems Laboratory (WI)** Fall, Spring
(4.0 cr; Prereq-3333, 4031W, [IT upper div or grad student]; A-F or Aud, fall, spring, every year)
Material from courses is applied to analyze operation/control of engines, power plants, and heating/ventilation systems. Emphasizes principles underlying performance characteristics of devices, measurement techniques, interpretation of experimental data, and presentation of results.

ME 5113 **- Aerosol/Particle Engineering** Fall
(4.0 cr; Prereq-IT upper div or grad student; A-F or Aud, fall, every year)
Kinetic theory, definition, theory and measurement of particle properties, elementary particle mechanics, particle statistics; Brownian motion and diffusion, coagulation, evaporation and condensation, sampling and transport.

ME 5446 **- Introduction to Combustion** Fall
(4.0 cr; Prereq-IT upper div or grad student, 3321, 3322; A-F or Aud, fall, every year)
Thermodynamics, kinetics, energy and mass transport, and pollutants in reacting systems. Reactors, laminar and turbulent flames. Ignition, quenching, and flame stability. Diffusion flames. Combustion in reciprocating engines, furnaces, and turbines, with emphasis on internal combustion engine performance and emissions.

VII. Conduct

"The Institute of Technology expects the highest standards of honesty and integrity in the academic performance of its students. Any act of scholastic dishonesty is regarded as a serious offense, which many result in expulsion." (Institute of Technology Bulletin, 1993-present).

All students in the Department of Chemical Engineering and Material Science are expected to abide by the highest professional ethical standards. See <http://it.umn.edu/students/policies/> for links to more regulations regarding academic integrity and disruptive behavior. The Office for Student Conduct and Academic Integrity (OSCAI) <http://www1.umn.edu/oscai/> covers Student Conduct and Academic Integrity.

VIII. Institute of Technology and University of Minnesota Policies

The Undergraduate Catalog is a valuable source of official information on all aspects of academic and student life. Rules and procedures about changing majors, Honor Points, GPA requirements, Liberal Education Requirements, dropping and adding classes, entrance to upper division, etc., are contained in this publication and on the IT website <http://it.umn.edu/students/policies/index.html>. The Undergraduate Catalog
<http://www.catalogs.umn.edu/ug/index.html> also has course descriptions of all IT courses - particularly useful when you are considering technical electives.

IX. Double Majors

If you wish to pursue a second major in IT you must file a petition and seek IT advising in 130 Lind. It usually requires five or more years to complete a double major program. Two double majors that are possible in four years, particularly if you have advanced placement credits, are Chemistry and Chemical Engineering; and Materials Science and Chemical Engineering.

Chemistry/Chemical Engineering*(adapted from < http://www.chem.umn.edu/undergrad/UGCur.html >)

In order to avoid class-time conflicts with the necessary Chemistry courses, this recommended sequence of courses differs from the typical course plan. Please see the Chemistry Department website for details.

This program is designed for IT students who wish to obtain a double major in Chemistry and Chemical Engineering. This plan fulfills the ChEn technical requirements. Talk to an advisor in Chemistry about the options for Advanced Chem Lecture and Lab Electives.

NOTE: Program varies depending on which term you begin. See advisors for updates.

Freshman Year

Fall Semester	Spring Semester
Chem 1021 Chemical Principles I (4 cr)	Chem 1022 Chemical Principles II (4 cr)
Math 1271 Calculus I (4 cr) +	Math 1272 Calculus II (4 cr) +
Phys 1301 Introductory Physics I (4 cr)	Phys 1302 Introductory Physics II (4 cr)
WRIT 1301 Univ Writing & Critical Reading (4 cr)	Biol 1009 General Biology (4 cr)

Sophomore Year

Fall Semester	Spring Semester
Chem 2301 Organic Chemistry I (3 cr)	Chem 2302 Organic Chemistry II (3 cr)
Chem 3502 Physical Chemistry II (3 cr)	Chem 3501 Physical Chemistry I (3 cr)
Math 2263 Multivariable Calculus (4 cr) +	ChEn 4001 Material & Energy Balances (4 cr)
MatS 3011 Intro to the Science of Materials (3 cr)	Math 2243 Linear Algebra & Differential Equations (4 cr) +

Junior Year

Fall Semester	Spring Semester
Chem 2311 Organic Chemistry Lab I (4 cr)	ChEn 4006 Mass Transfer and Separations (4 cr)
Chem 4701 Inorganic Chemistry Lect (3 cr)	ChEn 4102 Reaction Kin & Reactor Eng (4 cr)
ChEn 4101 Chem Eng Thermodynamics (4 cr)	ChEn 4201 Computational Methods in ChEn (3 cr)
ChEn 4005 Momentum & Heat Transfer (4 cr)	Chem 4121 Process Analytical Chemistry Lab (3 cr)
Advanced Chemistry Lab (2 cr)	

Senior Year

Fall Semester	Spring Semester
ChEn 3701 Intro to Biomolecular Eng (3 cr) #	ChEn 4502 Chem Eng Process Design II (2 cr)
ChEn 4214 Polymers (3 cr) ##	ChEn 4601 Process Control (3 cr)
ChEn 4401 Chemical Engineering Lab I (3 cr)	ChEn 4402 Chemical Engineering Lab II (2 cr)
ChEn 4501 Chem Eng Process Design I (3 cr)	Advanced Chemistry Lab (2 cr)
Advanced Chemistry Lecture Elective (3 cr)	

+ Math 1371, 1372, 2373, 2374 sequence is preferred by Chemical Engineering.
* Program layout does not contain all college or liberal education requirements.
# ChEn 3701 gets moved to Sr. year to accommodate Chem 4701. See Prof. McCormick if you need to make a substitution.
You can take Chem 5221 instead and it will cover the Adv. Chemistry Lecture Elective for the Chemistry requirements. If you do that, you need to make up 2 elective credits at some point.

Materials Science and Engineering and Chemical Engineering

The program combines the Chemical Engineering and Materials Science and Engineering upper division courses and is designed to satisfy the requirements for a Bachelor's degree for both majors. Normally, substitutions from the listed courses are not recommended. Students wishing to enter this program should apply via petition at the end of their second year, or no later than the end of their third year. You must meet the GPA admission requirements of both programs.

The following course plan is designed for students declaring a double major:
CHEN and MatS double major, lower division

Math 1371, 1372, 2373, 2374	16 credits
Physics 1301, 1302	8 credits
Chem 1021, 1022, 2301, 2302, 3501	17 credits
AEM 2011	3 credits
CSci 1107	3 credits
WRIT 1301 (or equivalent)	4 credits

Biol 1009 (or equivalent)	4 credits
CHEN 4001	4 credits
MatS 3011	3 credits
CHEN and MatS double major, upper division	
AEM 3031, 4511	6 credits
Chem 2311, 3502	6 credits
CHEN 3701, 4004, 4005, 4006, 4101, 4102	31 credits
4401, 4402, 4501, 4601 (not 4502)	
MatS 3012, 3801, 3851, 4013, 4212, 4214	27 credits
4221, 4301, 4400	
Liberal Education Requirements (6 courses)	15 credits
Total credits	147 credits

X. Research, Internship, and Co-op Experiences

Many opportunities exist on campus and in the department for undergraduates to participate in a research project, usually with a graduate student or postdoctoral associate under the supervision of a faculty member. Participating in a research project is a very good way to develop the skills research requires. It also provides an excellent opportunity for getting to know professors so they can write more extensive letters of recommendation for employment or graduate studies. For students considering graduation school, this is the best way to sample graduate student life. Use the department research brochure on the department website <http://www.cems.umn.edu/research_areas/index.php>to identify professors doing research in chemical engineering that interests you.

Getting Technical Elective Credit for Unpaid Academic Research
A student may earn academic credit for research in faculty laboratories, under a faculty advisor, which may apply toward the Chemical Engineering technical elective requirements. The upper limit of credits so applied is two. To apply for technical elective credit, the following conditions must pertain: 1) the student is not paid for the research; 2) the student is registered for the undergraduate Chemical Engineering Directed Research course (CHEN 4594); 3) student has a project report or presentation graded by the supervising faculty member, who then assigns the course grade. Please see Ms. Laura Ericksen for an application and procedures form (Form 1014 Technical Elective Approval Form).

The number of credits you may register for in CHEN 4594 is determined by your faculty advisor. In general, each credit entails 3-4 hours of work related to the lab each week over the course of the semester. Besides the work actually done in the lab, related work outside the lab, such as literature searches, calculations, and report preparation should also be taken into account.

Co-op Program
The Department of Chemical Engineering and Materials Science supports both Industrial Internships and Co-op Industrial Assignments for undergraduates. Please see the program description and procedures at: <http://www.cems.umn.edu/downloads/ug/coop_mse.pdf>. If you have questions about the Co-op program please contact Prof. David Shores (108 Amundson, 612-625-0014, dshore@umn.edu).

Finding opportunities for paid summer internships

Excellent industrial or research experience can be gained without interfering with your studies through the many summer internship positions announced and posted at the IT Career Services office (50 Lind Hall; <http://www.ccse.umn.edu/index.php>; (612) 624-4090; ccse@umn.edu) and on the Undergraduate Bulletin Board over the course of the year. Interviewing for industrial summer positions is generally conducted at the IT Career Services Office well in advance of the summer – often in the preceding *fall*. Be sure to sign up early! Industrial summer internship opportunities become almost equivalent to coop experiences when the guidelines are followed to receive academic credit (see <http://www.cems.umn.edu/downloads/ug/coop_mse.pdf>.

There are also opportunities to get paid for research work on campus as an Engineering Assistant Trainee (but in most cases no academic credit can be obtained – see guidelines below). When such opportunities arise, they are arranged directly by the faculty member who is hiring. Many faculty members inform Prof. Daoutidis about positions in relation to the Honors Program. If you qualify for work-study, be sure to tell your supervising professor so that they might be able to arrange coordination with your financial aid package.

Moreover, several centers on campus (e.g., the Minnesota Supercomputing Institute) conduct summer internship programs. Notices about these are posted as available on the Undergraduate Bulletin Board. Finally, the University provides Undergraduate Research Opportunity Program (UROP) awards; applications are available in 130 Lind. Awards are normally made twice a year for limited stipend and research expenses.

XI. Scholarships (Department and IT)

In the spring some scholarships are awarded by the Institute of Technology. Students must apply for the IT scholarships (applications available early in the Spring semester and at the IT Student Services Office in 130 Lind).

Department scholarships are awarded in the Spring semester for the following year. These scholarships also require an application distributed in early Spring semester by email. The department sometimes has sponsored scholarships to offer students. When these exist students are notified of their availability and application requirements where applicable. Many IT and department scholarships cannot be awarded if you have not applied for financial aid. Be sure to apply for financial aid at the Office of Student Finance (200 Fraser; 612-624-1111) or, if appropriate, at the International Students and Scholar Services office (190 HHH; 612-626-7100; <http://www.isss.umn.edu>. These offices are also an excellent source of other scholarship announcements.

XII. Caution Against Working While Studying

Beware the danger of getting behind in your coursework, especially in upper division. You should expect that course work will be very demanding. Even without part-time work many students find themselves having to adjust their study habits and manage their time more carefully when entering upper division. Working part-time is challenging for anyone carrying a full course load, and it is rare that anyone working fifteen hours a week or more during the semester can learn and perform up to their potential and still graduate in four years. If you opt for a lower course load, be sure to schedule courses carefully.

Many U of MN students hold part-time jobs while pursuing their degrees, and though some jobs provide educational technical experiences as well as financial benefits, you should remain aware that pursuing a full course load is itself a full time job.

Excellent industrial and research experience can be gained without interfering with your studies through the many summer internships announced and posted on the Undergraduate Bulletin Board throughout the year.

XIII. Study Abroad

Students who are interested in exploring foreign cultures may be able to arrange up to one year of study in a university in a foreign country. Many courses taken in a university abroad can be transferred for credits. However, it is likely that the graduation date will be delayed beyond the normal four-year period. Students who are interested in studying abroad are urged to consult with the Learning Abroad office (<http://www.umabroad.umn.edu/>; 230 Heller Hall; 612.626.9000) and with the Director of Undergraduate Studies (433 Amundson; mccormic@cems.umn.edu; 612-625-1822) as early as your Freshman year. It may be easiest to study abroad in the Sophomore year or after the CHEN core courses are completed.

Adam Pagel (105 Lind; pagel@umn.edu; 612-624-8013) is the IT advisor for issues related to study abroad programs and international students. Be sure to consult him when making plans.

XIV. Honors Degrees and the Upper Division CHEN Honors Program

You may earn the BChE degree with one of the honors designations *cum laude*, *magna cum laude* or *summa cum laude* if the following requirements are satisfied and proper applications submitted:

***Cum laude*:**
Complete one upper division honors experience.
Attain an overall grade point average of at least 3.50 in all upper division course work.
Attain an overall grade point average of at least 3.50 in all courses required by the upper division Chemical Engineering program.
Complete and have approved a Senior honors thesis.

Magna cum laude:
Complete two upper division honors experiences (one of which must be research).
Attain an overall grade point average of at least 3.66 in all upper division course work.
Attain an overall grade point average of at least 3.66 in all courses required by the upper division Chemical Engineering program.
Complete an approved Senior honors thesis.

Summa cum laude:
Complete three upper division honors experiences (two of which must be research experiences).
Attain an overall grade point average of at least 3.75 in all upper division course work.
Attain an overall grade point average of at least 3.75 in all courses required by the upper division Chemical Engineering program.
Complete an approved Senior honors thesis.

You may apply to participate in the upper division Honors Program upon entering the upper division Chemical Engineering program. Make an appointment with the Honors Program advisor, Prof. Daoutidis at, daoutidi@cems.umn.edu, to discuss proposed honors experiences. Bring a copy of your transcript to your appointment. When the two of you agree on an individual honors program, you should file the "Graduation with Honors-Preliminary" form with the IT Honors Office (available in 136 Lind). At the beginning of your graduation semester you should again make an appointment with Prof. Daoutidis to verify the satisfactory completion of all honors experiences. You should then file the Honors Degree Final Application form (available from and to be filed in the IT Honors Office) no later than five weeks prior to the planned graduation date.

Honors experiences can include the following:

1. Participation in supervised undergraduate research projects during the school year or in the summer (e.g., UROP), whether they are undertaken for academic credit or not.
2. Completion of special design or independent study projects supervised by faculty members.
3. Completion of graduate 8000-level courses (in Chemical Engineering or in other programs) or, with the approval of the Honors Program advisor, completion of honors or advanced undergraduate courses in programs other than Chemical Engineering. Advanced undergraduate courses in Chemical Engineering cannot be used as honors experiences.

When proposing honors experiences, bear in mind the following guidelines:
1. An honors experience is something *in addition* to the requirements for the BChE degree.
2. An honors experience must be *evaluated* by a faculty member, so industrial research experiences can be used only with arrangements made for an evaluation method.
3. Research projects done as part of the lower division honors program will not normally be accepted as honors experiences for the upper division CEMS program. The two programs are separate.

Even without participating in the Honors program, you will still automatically receive your bachelor's degree with the designations *with distinction* or *with high distinction* if your overall grade point average is in the ranges of 3.50-3.79 and 3.80-4.00, respectively.

XV. Requirements for Chemistry Minor

The Chemistry courses required for the BChE degree automatically qualify you for a Chemistry minor. You do not need to apply to the Chemistry Department for the Chemistry minor – it should appear on your record automatically with your BChE degree.

XVI. AIChE Student Chapter

The American Institute of Chemical Engineers (AIChE) student chapter has an office in Room 132B, and Prof. Caretta is the advisor. The AIChE is the primary professional organization for chemical engineers, and you can join as a student. The student chapter sponsors informational, educational, and social meetings, which include visits from corporate representatives and recruiters.

XVII. Selected Facilities and Organizations of Interest

IT Student Services
Most of the college business you will need to deal with is taken care of in 130 Lind Hall – IT Student Services – (612) 624-8504. See advisors there about petitions, probation, transfer admissions, your degree clearance, and college policies.

Lower Division Advising
Before you are admitted to the upper division Chemical Engineering program you should get your advising from lower division (128 Lind Hall, (612) 624-2890).

Computer Facilities
The Department of Chemical Engineering and Materials Science has an undergraduate study room in Amundson 132. There are computers for the exclusive use of CEMS undergraduates. In addition there are IT computer labs in several locations exclusively for IT students. Finally, even more University facilities (ADCS – Academic Distributed Computed Services) are available to you around campus.

Counseling

University Counseling Services in Eddy Hall offers a wide variety of services and provides help with problems ranging from improving study skills, making career decisions and improving communication skills to controlling anxiety, and stress and time management.

Libraries
There are many library collections at the University. For a complete list see the library website at: <http://www.lib.umn.edu/>. All of the libraries have study areas. The libraries closest and most useful to you are:

Science and Engineering Library	Walter Library
Mathematics Library	310 Vincent Hall
Bio-Medical Library	Diehl Hall
Wilson Library (main library)	Wilson Library (on the West Bank)

Placement – summer and permanent
The IT Career Services Office is in Room 50, Lind Hall; (<http://www.ccse.umn.edu/index.php>; (612) 624-4090; ccse@umn.edu). Every year, particularly in the Fall Semester, companies seeking to hire engineers set up interview schedules through the Career Services Office. You should register there, browse through their collection of company brochures, and sign up for interviews both for summer internships and for permanent employment.

Study Areas
Amundson 132 is the principal study room for Chemical Engineering undergrads in Amundson Hall. Other locations include levels one and two in EE/CSci and the Taylor room in 150 Lind Hall. Walter Library and other libraries have large study areas as well.

Student Organizations
There are student organizations for virtually every interest – sports, hobbies, politics, religion, arts, student government, professions, music, travel, ethnic culture, and many, many others. The Coffman Memorial Union website is a good resource for research what groups exist. Go to the <http://www.coffman.umn.edu/> website and click on “Get Involved”. Some engineering student groups include: the Society of Women Engineers, the IT Student Board, the IT Board of Publications, Tau Beta Pi, and Plumb Bob. See the University of Minnesota website for contact information for all of these groups.

Tutoring
The IT undergraduate academic center in 150 Lind provides free one-on-one tutoring by experienced students for help with math, physics, and chemistry problems.

XVIII. Graduation

You should review your Academic Progress Audit System report (APAS, available through your OneStop account on the Web <http://onestop.umn.edu/onestop/index.html>, click on APAS report) at least two semesters before you plan to graduate. The APAS report should be an exact statement of the courses you must successfully complete in order to finish your BChE degree. WARNING: The Registrar’s software is known to make errors. If corrections are needed in your lower division coursework, Liberal Education electives, Writing Intensive requirements, or Residency requirements, see IT Student Services.

You must complete and submit an online *Application for Degree* form at the beginning of the semester you plan to graduation. The application is available at the OneStop web site: <http://onestop.umn.edu/onestop/graduating.html>. The *Application for Degree* form is used by the Office of the Registrar to begin the degree clearance process.

Application deadlines for each graduation are published on the web at: <http://onestop.umn.edu/onestop/calendar.html>.

XIX. Faculty Addresses and Phone Numbers

AYDIL, Eray, Professor, 235c AmH, **5-8593,** aydil@umn.edu
BATES, Frank S., Distinguished McKnight University Professor, Regents Professor and Head, 391 AmH, **4-0839**, bates@cems.umn.edu
BHAN, Aditya, Assistant Professor, 410 AmH, **6-3981**, abhan@umn.edu
CARETTA, Raul A., Professor, 151b AmH, **5-8066**, caretta@umn.edu, Unit Ops Lab 350a AmH 6-2019, Undergrad AIChE Advisor
COCOCCIONI, Matteo, Assistant Professor, 204 AmH, **4-9056**, matteo@umn.edu
CUSSLER, Edward L., IT Distinguished Professor, 301 AmH **5-1596**, cussler@cems.umn.edu
DAOUTIDIS, Prodromos, Professor, 291 AmH, **5-8818**, daoutidi@cems.umn.edu, Honors and Research adviser
DAVIS, H. Ted, Regents Professor. 151c AmH **5-4088**, davis@cems.umn.edu
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