MMAE Guide to Graduate Studies

Illinois Institute of Technology

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Chapter 1

Introduction

This guide serves as a supplement to the IIT Graduate Bulletin[1] and as a checklist for graduate students with regard to the Mechanical, Materials and Aerospace Engineering (MMAE) Department's procedural requirements and deadlines. Deadlines are established by the Graduate College, and are also listed in the current IIT Graduate Bulletin. All Graduate College forms referenced in these guidelines are available for download. The Graduate Student Handbook is another university publication that discusses the university's academic policies for graduate students and answers students' most frequently asked questions. It is the student's responsibility, with guidance from his/her adviser, to follow the procedures and meet the specified deadlines. These deadlines are not flexible and failure to meet them will result in postponement of the student's graduation. For your reference, this guide is available on the MMAE departmental web site.

Contacts:

Chair:	Prof. Jamal Yagoobi
Associate Chair for Graduate Programs:	Prof. Kevin Cassel
Department Coordinator:	Mr. Rob Seal

The MMAE faculty has the ultimate responsibility for the comprehensive departmental program. The Chairman of the Department, in consultation with the faculty, appoints faculty members to serve on the Graduate Studies Committee (GSC). The GSC approves all ordinary procedural matters, which include student programs of study and appointments of committees to evaluate student examinations. When extraordinary changes in degree programs or in departmental policies are warranted, the GSC will make recommendations to the faculty for discussion and approval. The Associate Chair leads the Committee and handles the day-to-day obligations of the graduate studies program,

[1] Blue text in the electronic version of this PDF document provides links to the specified resources or information within this document or on the IIT or MMAE web sites.

including graduate admissions and new student advising. The committee meets once a month during the academic year.

1.1 MMAE Graduate Programs

The MMAE Department offers graduate programs in Mechanical and Aerospace Engineering (MAE), Materials Science and Engineering (MSE), and Manufacturing Engineering (MFG). The degrees that the department offers are summarized below.

Mechanical and Aerospace Engineering (MAE)

- Master of Science in Mechanical and Aerospace Engineering (MSMAE)
- Master of Mechanical and Aerospace Engineering (MASMAE)
- Doctor of Philosophy in Mechanical and Aerospace Engineering (PhD-MAE)

Materials Science and Engineering (MSE)

- Master of Science in Materials Science and Engineering (MSMSE)
- Master of Materials Science and Engineering (MASMSE)
- Doctor of Philosophy in Materials Science and Engineering (PhDMSE)

Manufacturing Engineering (MFG)

- Master of Science in Manufacturing Engineering (MSMFG)
- Master of Manufacturing Engineering (MASMFG)

1.2 General Operating Procedures

1.2.1 Advising Procedures

The Associate Chair serves as the temporary adviser to all new graduate students who do not have a thesis advisor and the permanent advisor to master of engineering (MAS) students. M.S. and Ph.D. students are encouraged to find a permanent thesis advisor as soon as possible. To change permanent advisers, a student needs to complete Form 410, Change of Adviser. All students are required to submit a Form 401, Program of Study before the beginning of the second semester for full-time students or before enrollment beyond 9 credit hours for part-time students. All graduate students are advised to update their mailing addresses, email addresses, and/or telephone numbers on myIIT so that IIT has accurate contact information.

Students should consult with their advisers as early as possible in order to plan their courses. Students registering for any of the following courses require an online registration override from their adviser prior to registering:

- MMAE 591 Research and Thesis for M.S. Degree[2]
- MMAE 594 Project for Professional Masters Degree[3]
- MMAE 691 Research and Thesis for Ph.D. Degree
- MMAE 600 Continuation of Residence

Students registering for MMAE 597 Advanced Topics must obtain an online registration override from the corresponding instructor prior to registering.

1.2.2 Registration Procedures

The schedule of classes for each semester is available on the myIIT portal, where students can also register for classes. After having the course selection approved by the student's advisor, the advisor will provide a term-specific Alternate PIN, which is required during the online registration process. Other holds may be placed on student accounts by various departments such as the Graduate College and the Bursar's Office. For example, students who have not submitted a Program of Study prior to completing nine credit hours, or those who owe tuition or fees, will have their registration withheld until such matters have been settled. Students are encouraged to check their accounts for holds prior to registering in order to clear them in a timely fashion. Continuing full-time students may register in advance in April (for fall semester) and November (for spring semester).

A student is considered full-time in a given semester if he/she has enrolled for at least 9 credit hours or holds a fellowship or teaching/research assistantship. International students with a teaching/research assistantship or a full-time fellowship must register for at least 6 credit hours to be considered full time. All students who do not meet the above criteria are considered part time. International students must maintain full-time status in each semester (excluding summers) during their studies at IIT. Under a limited set of circumstances, this requirement can be waived. To do so, the international student must fill out the Less than Full-Time Enrollment Eligibility Form with their advisor and submit it to the International Center. For example, it is not necessary to register for nine credit hours in the semester in which the student will complete the degree program.

Graduate students receiving financial assistance from the department in the form of a research or teaching assistantship are required to register online before the first day of classes. Tuition vouchers will then be electronically prepared and approved by the Department Chairman, the Dean of Armour College, and

[2]Master of Science students - MSMAE, MSMSE or MSMFG

[3]Master of Engineering students - MASMAE, MASMSE or MASMFG

the Dean of the Graduate College. A Department Administrator will obtain these approvals provided that students are registered by the deadline.

1.2.3 Program of Study

Students are required to select courses with guidance from their adviser and submit an electronic 401 Program of Study Form before the beginning of the second semester for full-time masters students or before completing nine credit hours for part-time masters students. Ph.D. students who have earned a masters degree must file a Program of Study before beginning the second semester, or before completing nine credit hours. Doctoral students without a masters degree must file an approved Program of Study before completing 27 credit hours in the Ph.D. program. The Program of Study form, once approved by the adviser, also requires the approval of the GSC, the Chairman of the Department, and the Dean of the Graduate College. Note that GSC and departmental approval takes place during regularly scheduled meetings each month during the academic year. Therefore, students should allow sufficient time for approval, particularly before the beginning of each semester. Once a student has filed an approved program of study, deviation from the plan requires the same approvals of Form 406, Change in the Program of Study, as on the original Program of Study. It is the student's responsibility to be sure that the Program of Study and actual courses taken match by the beginning of the semester in which the student is to graduate.

Note the following when devising a Program of Study:

- All full-time students must register each semester for the department seminar, MMAE 593. See section 1.2.6.
- Degree-seeking students may take up to six credit hours of accelerated courses.
- Non-MMAE courses may be taken as elective courses with adviser and GSC approval on Form 401. Note that Manufacturing Technology (MT) courses are NOT permissible as elective courses for MMAE degrees.
- Up to nine credit hours of transfer credit from other institutions is permitted if a grade of B, or better, is obtained and the courses were not taken to meet the requirements of another completed degree. These courses are included in the appropriate section of Form 401, and students are asked to provide course syllabi and/or descriptions for evaluation in the approval process.
- A maximum of nine credit hours of non-core courses can be taken at the 400 level in the MAE program provided that the courses were not taken to fulfill undergraduate degree requirements.
- A maximum of twelve credit hours at the 400 level can be taken in the MSE program provided that the courses were not taken to fulfill undergraduate degree requirements.

1.2.4 Degree Program Changes

Students who have been admitted to a MS or PhD program within the MMAE Department who wish to switch to the MAS (or MS in the case of PhD) program within the department must follow the following procedure:

1. Discuss the reasons for the change with the student's current advisor and obtain their endorsement.

2. Meet with the Associate Chair to discuss the specifics of the change. For example, it is possible that not all courses taken toward the previous degree may be applied to meet requirements in the new degree.

3. Fill out a new Form 401, Program of Study indicating the new degree and reflecting the courses that have been taken and will be taken to meet the degree requirements. Note that no more than four credit hours of MMAE 591 or 691 may be applied toward the 30 credit hour requirement for the MAS degree. Upon approval by the GSC and the Graduate College, the new 401 form will supersede the student's previous program of study, and the student will be officially enrolled in the new degree program.

Note that the above procedure only applies to students changing programs within the MMAE Department. Changing programs between departments requires submission of a new application.

1.2.5 Departmental Financial Assistance Policy

The Department of Mechanical, Materials and Aerospace Engineering has a limited number of teaching assistantships available to graduate students in the department who show high potential for success in the programs and have the necessary teaching skills. Applications are sought near the end of each semester for the following term. The Department Chair, in consultation with the Associate Chair for Graduate Programs, awards these assistantships to the most qualified students for a certain period of time during their degree programs. In order to make these awards to as many deserving students as possible, teaching assistantships are typically awarded for a maximum number of semesters as follows:

- Master of Science students: 2 semesters

- Ph.D. students: 4 semesters

Master of Engineering students are not eligible for teaching assistantships. The availability of these assistantships is dependent upon funding and the needs of the department. Students are encouraged to pursue a research assistantship as early as possible in their program. Research assistantships are available to full-time Master of Science and Doctor of Philosophy degree students and are awarded by individual faculty members.

The IIT Office of Financial Aid offers financial assistance to graduate students in the form of work opportunities and loans. Please consult their website for further information.

1.2.6 MMAE Seminar

All full-time MMAE students must register for the Department Seminar Series MMAE 593 every semester. The seminar is a no fee, no credit class, but registration and attendance is mandatory. The seminar is a pass/fail class and will be graded on attendance. A student will receive a passing grade if he/she attends a minimum of 80 percent of the seminars offered in that semester. Students must register for the seminar every semester they are a full-time graduate student. They must pass the seminar $I \geq x$ times in the following formula $x = (n+1)/2$, where I is an integer and n is the number of semesters a student is enrolled as a full-time graduate student. For example, a typical masters student is enrolled full-time four semesters and would need to pass the seminar $(4 + 1)/2$, or 3 times. Please note that this is a departmental graduation requirement.

1.2.7 Academic Probation

A student whose cumulative GPA falls below 3.0 is placed on academic probation for the following semester. If on probation, the student must meet with the Graduate College, Office of Academic Affairs, to fill out Form 702, Academic Probation Contract, before registering for classes. This form must also be signed by the student's advisor. Students on academic probation must not receive any grade below a B while their overall GPA is below 3.0. If a student's GPA in his or her approved program of study is below 3.0, then graduate courses approved on Form 406 may be added to the program until the corresponding GPA is at least 3.0.

1.2.8 Repeating a Course

Students may repeat up to two distinct courses, with each course being repeated once. Both grades will be recorded on the student's transcript, and the grade used in the calculation of the GPA will be the latest recorded. Re-registration to repeat a course will require the permission of the student's adviser, Department Chair, and the Associate Dean for Academic Affairs, and will also require completion of the Course Repeat/Audit Form. This form must be submitted at the time of registration and can be accessed online at www.enrollment.iit.edu/forms.

1.2.9 Leave of Absence

Admitted degree seeking students are expected to maintain continued registration (excluding summer semesters) until graduation unless they are granted a leave of absence from the Dean of the Graduate College. For this purpose, use Form 216, Request for Leave of Absence. A student who withdraws without permission, or who lets a granted leave of absence expire, must apply to the department for readmission. If less than three years has lapsed since the student registered, readmission normally requires a letter of endorsement from the student's adviser to the Dean of the Graduate College. For absences of three years or more, a new application and supporting documents (transcripts, letters of recommendation, etc.) are required.

1.2.10 Non-Degree Seeking Status

A student who has not obtained admission to a degree program may seek to register as a non-degree seeking student. Non-degree seeking graduate students must complete an application form and submit an official transcript of all previous undergraduate and graduate work to the Graduate Admissions Office. The minimum requirements for permission to register, set by the Graduate College, are a bachelor's degree from an accredited institution and a GPA of a minimum of 2.5/4.0 or equivalent. Foreign students with F-1 visas issued at the request of IIT may not be enrolled as non-degree seeking graduate students. All non-degree graduate student applicants planning to take MMAE courses must obtain the approval of the Associate Chair, unless the student is advised directly by the Dean of the Graduate College.

A non-degree seeking graduate student must complete a minimum of six credit hours of eligible course work (maintaining a GPA of 3.0 or better) before submitting an application to become a regular graduate student in a degree program. Note that maintaining the minimum GPA requirement does not guarantee admission to the MMAE Department's graduate program. No more than nine credit hours of course work taken as a non-degree seeking graduate student may be applied towards the student's program of study for the degree.

1.2.11 Delayed Graduation

Students who do not complete the graduation requirements in the semester in which they have applied for graduation must do the following in the subsequent semester in addition to completing the missing requirements:

- Submit a new Graduation Application, Form 527 (the fee is waived). **AND**
- Register for one credit hour of GCS 600, Graduate Continuation of Studies, if all course hours and research is complete and the thesis defense is approved, but other degree requirements are incomplete such as thesis examiner document approval, change of program/courses (Form 401/406) and incomplete or missing course grade(s). Tuition for GCS 600 is at a reduced rate and does NOT force student to full-time status; therefore, this option is not available to international students. **OR**
- Register for MMAE 591 or 691 for a minimum of one credit hour at the usual tuition rate. This does force student to full-time status.

Chapter 2

Masters Students (MS and MAS)

2.1 Degree Requirements

Students with bachelors degrees in mechanical engineering, materials science and engineering, aerospace engineering or other related fields are eligible to apply for masters degrees in the MMAE department. Once admitted the student's advisor will help the student formulate a program of study that includes 30 credit hours for the non-thesis Master of Engineering degrees or 32 credit hours for the Master of Science degrees, which include research and a thesis. The Master of Engineering degrees are course-only programs that may include a project. The Master of Science degrees require 6–8 credit hours of MMAE 591, Thesis and Research for MS Degree, which is included in the total of 32 required credit hours. The M.S. degrees require completion of a thesis based on the student's research and a Masters Comprehensive Exam during which the student presents his/her research.

2.1.1 Mechanical and Aerospace Engineering (MAE)

All MAE students are expected to demonstrate proficiency in Engineering Analysis, normally accomplished by taking one or two courses. Masters students select a major area from five basic areas of study: Fluid Dynamics, Thermal Sciences, Solids and Structures, Design and Manufacturing, Dynamics and Controls, or a specialization in Energy/Environment/Economics (E^3). M.S. students are required to take the core course for their chosen major area, several non-core courses in their major area and six to eight credit hours of thesis. Master of engineering students are required to take an engineering analysis course, one course that emphasizes numerical methods, and the core course(s) in their major area. The core courses corresponding to the five major areas are:

- Fluid Dynamics: MMAE 510 Fundamentals of Fluid Mechanics

- Thermal Sciences: MMAE 525 Fundamentals of Heat Transfer
- Solids and Structures: MMAE 530 Advanced Mechanics of Solids
- Dynamics and Controls: MMAE 541 Advanced Dynamics
- Design and Manufacturing: MMAE 545 Advanced CAD/CAM

The approved MMAE courses that emphasize numerical methods are:

- MMAE 451/CAE 442 Finite Element Methods I
- MMAE 517 Computational Fluid Dynamics
- MMAE 532/CAE 530 Finite Element Methods II
- MMAE 538/CAE 534 Computational Techniques in FEM
- MMAE 544 Design Optimization
- MMAE 570 Computational Methods in Materials Processing

Courses offered by other departments with an emphasis in numerical methods can also be used to satisfy the numerical requirement. Such requests must appear on the 401 form and will be considered on a case-by-case basis by the GSC. The required courses for the MAS and M.S. degrees in MAE are listed in the tables below.

2.1.2 Materials Science and Engineering (MSE)

Master of Science in MSE students must complete 12 core credit hours as outlined in the following tables. The remaining 20 credit hours are fulfilled by non-core courses and thesis research. Master of engineering students are required to complete the same core 12 credit hours as listed for the M.S. students. The student's adviser and the GSC must approve the remaining 18 credit hours. Slightly different courses are required for students specializing in ferrous metallurgy. The required courses for the MAS and M.S. degrees in MSE are listed in the tables below.

2.1.3 Manufacturing Engineering (MFG)

All manufacturing engineering students are expected to complete six core credit hours. Students must select either a mechanical and aerospace (MAE) or a materials science and engineering (MSE) emphasis. Students are required to take additional courses depending on their area of emphasis. The remaining credit hours must be fulfilled by elective courses approved by the adviser and the GSC. Students in the Master of Science program must take six to eight credit hours of thesis. The required courses for the MAS and M.S. degrees in MSE are listed in the tables below.

2.2 Master of Science Programs (M.S.)

In the following tables, see chapter 4 for a list of engineering analysis, core and elective courses in each major area.

2.2.1 Master of Science in Mechanical and Aerospace Engineering

Engineering analysis courses:	MMAE 501 and MMAE 502 (6 credits)
Core course in major area:	3-4 credits
Non-core courses in major area:	Minimum 6 credits
Thesis research:	MMAE 591 Thesis (6-8 credits)
Remaining hours:	Elective courses if needed
Total hours:	**32**

2.2.2 Master of Science in Mechanical and Aerospace Engineering with E^3 Specialization

Engineering analysis courses:	MMAE 501 and MMAE 502 (6 credits)
Core courses in major area:	MMAE 520, MMAE 523 and CHE 543
Non-core courses in major area:	2 courses from Group A and one course from Group B
Thesis research:	MMAE 591 Thesis (6-8 credits)
Remaining hours:	Elective courses if needed
Total hours:	**32**

Group A: MMAE 521, MMAE 524, MMAE 525, MMAE 526, MMAE 527

Group B: CHE 541, CHE/MMAE 560, CHE 587, EM 507, ENVE 501, ENVE 506, ENVE 520, ENVE 527, ENVE 542, ENVE 545, ENVE 551, ENVE 561, ENVE 563, ENVE 570, ENVE 573, ENVE 577, ENVE 578, ENVE 580, ENVE 585

2.2.3 Master of Science in Manufacturing Engineering

MAE Emphasis

Core courses:	18 credits including: MMAE 545 MMAE 546 MMAE 547 MMAE 560 One materials course One course emphasizing numerical methods
Manufacturing courses:	6-8 credits
Thesis research:	MMAE 591 Thesis (6-8 credits)
Total hours:	**32**

MSE Emphasis

Core courses:	15 credits including: MMAE 547 MMAE 560 MMAE 445, 545, 546, or 576 MMAE 444, 475, 574, 575, or 577 One course emphasizing numerical methods
Manufacturing courses:	9-12 credits
Remaining hours:	MMAE 591 Thesis (6-8 credits)
Total hours:	**32**

2.2.4 Master of Science in Materials Science and Engineering

Core courses:	12 credits including: MMAE 563 MMAE 569 MMAE 468 or 486 MMAE 470, 579, or 580
Non-core courses in materials:	12-14 credits
Thesis research:	MMAE 591 Thesis (6-8 credits)
Total hours:	**32**

2.3 Master of Engineering Programs (MAS)

2.3.1 Master of Mechanical and Aerospace Engineering

Engineering analysis courses:	MMAE 501 (6 credits) and MMAE 502 or course emphasizing numerical methods
Core course in major area:	3-4 credits
Elective courses:	20-21 credits
Total hours:	**30**

2.3.2 Master of Mechanical and Aerospace Engineering with E^3 Specialization

Engineering analysis course:	MMAE 501 (6 credits) and MMAE 502 or course emphasizing numerical methods
Core courses in major area:	MMAE 520, MMAE 523 and CHE 543
Non-core courses in major area:	2 courses from Group A and one course from Group B
Remaining hours:	Elective courses
Total hours:	**30**

Group A: MMAE 521, MMAE 524, MMAE 525, MMAE 526, MMAE 527

Group B: CHE 541, CHE/MMAE 560, CHE 587, EM 507, ENVE 501, ENVE 506, ENVE 520, ENVE 527, ENVE 542, ENVE 545, ENVE 551, ENVE 561, ENVE 563, ENVE 570, ENVE 573, ENVE 577, ENVE 578, ENVE 580, ENVE 585

2.3.3 Master of Manufacturing Engineering

MAE Emphasis

Core courses:	18 credits including: MMAE 545 MMAE 546 MMAE 547 or MMAE 557 MMAE 560 One materials course One course emphasizing numerical methods
Manufacturing courses:	12 credits
Total hours:	**30**

Note: The Master of Manufacturing Engineering with MAE emphasis may be taken entirely via the internet.

MSE Emphasis

Core courses:	15 credits including: MMAE 547 MMAE 560 MMAE 445, 545, 546, or 576 MMAE 444, 475, 574, 575, or 577 One course emphasizing numerical methods
Manufacturing courses:	15 credits
Total hours:	**30**

2.3.4 Master of Materials Science and Engineering

Core courses:	12 credits including: MMAE 563 MMAE 569 MMAE 468 or MMAE 486 MMAE 470, MMAE 579, or MMAE 580
Elective courses:	18 credits
Total hours:	**30**

Note: MMAE 470 or equivalent is a prerequisite for both MMAE 579 and MMAE 580.

Emphasis in Ferrous Metallurgy

Core courses:	15 credits including: MMAE 563 MMAE 569 MMAE 574 MMAE 575 MMAE 578
Elective courses:	15 credits
Total hours:	**30**

2.4 Completion of Studies and Graduation

Within two weeks of the start of the intended graduation semester, the student files an Application for Graduation Form with the Graduate Academic Affairs Office. Both M.S. and MAS students must submit this form. The application is valid only in the semester in which it is filed. If the student fails to graduate in the intended semester, then a new application must be filed for a later semester. After the application is filed, the Graduate College provides a form entitled, "The Sequence of Events and Deadlines," applicable to that semester. Note that students must be registered for a minimum of one credit hour in the semester in which they graduate, including the summer semester.

2.4.1 M.S. Students

Graduating M.S. students must submit Form 300, Masters Final Thesis or Comprehensive Exam Committee and Exam Scheduling, for approval by the GSC. The approved form must be submitted to the Graduate College no later than two weeks prior to the exam date. The examination committee consists of at least three faculty members whose purpose it is to evaluate the student's thesis and carry out the comprehensive examination. The committee includes the student's advisor, and one of the three faculty members must be a departmental representative from a discipline different than the student's major area of study. A mandatory thesis preparation discussion is held early each semester by the Thesis Examiner to assist students in preparing their thesis and alerting them to problems that may occur. The student's initial appointment with the Thesis Examiner must be made at least six weeks before the end of the anticipated graduation semester. The Thesis Examiner's schedule is posted in the Graduate College. Meetings are by appointment only. To make an appointment with the thesis examiner, contact Pat Johnson-Winston at 312- 567-3370 or winston@iit.edu. The MMAE student's thesis must conform to the guidelines given in the latest IIT Thesis Manual, which can be found on the thesis information web site. The latest version of the IIT Thesis Manual can be downloaded from this web site. Ready-made templates (Microsoft Word and LaTeX) can also be downloaded from this site.

The student prepares a preliminary draft of his/her thesis at least five weeks before graduation. The student must submit the preliminary draft to all thesis committee members and obtain the signed approval of his/her adviser, each member of the thesis committee, the Department Chair, and the Graduate College Thesis Examiner. This is accomplished using Form 501A, Preliminary Thesis Approval Form.

At least seven days prior to the comprehensive examination, the student distributes copies of the approved thesis draft to the thesis committee members. His/her adviser then emails all MMAE faculty members announcing the place and time of the examination. The email should include an abstract of the thesis. It is the student's responsibility to ensure that the email is sent on time. Failure to do so may result in rescheduling of the examination.

The thesis committee conducts a comprehensive oral examination on the student's thesis and related areas. The examination is open to all IIT faculty. The examination is scheduled at a mutually convenient time and date, but must be taken at least fifteen days prior to the end of the semester. The adviser reports the results of the examination to the department using MMAE Form 103, Results of Masters Comprehensive Examination (available in the MMAE main office to faculty members only) and Form 303, Masters Comprehensive/ Ph.D. Qualifying Exam (available in the MMAE main office to faculty members).

Exam results reported on Form 303 must be submitted to the Graduate College within 48 hours of the exam and received no later than one week prior to the last day of classes.

The student obtains signature approvals of the final thesis draft from his/her adviser, all thesis committee members, and the Department Chair on Form 501B, Final Thesis Approval. The student pays the advanced degree fee at the Bursar's office. At least nine days before commencement, the student meets with the Thesis Examiner for final thesis approval. The student should bring three unbound copies of the completed thesis in marked manila envelopes with their adviser's original signature on the title pages along with a Bursar's receipt showing payment of fee and Form 50lB bearing all approval signatures except that of the Thesis Examiner.

Note: The three thesis copies are bound and distributed to the library, the department archives, and the adviser. The Graduate College will not provide binding for more than three copies. Additional personal bound hard copies can be obtained by using IIT Office Services.

2.4.2 MAS Students

MAS candidates are not required to complete a thesis or a comprehensive examination. As a result of the successful completion of all required course work, the student graduates and is awarded a Master of Engineering Degree.

Chapter 3

Doctor of Philosophy (Ph.D.)

3.1 Degree Requirements

Although it is possible to apply directly to the Ph.D. program upon receipt of a bachelors degree, the majority of those entering the Ph.D. program will have already completed a Master of Science degree. Students who have earned a M.S. degree from IIT and wish to pursue a doctorate must reapply to the Graduate College through the Graduate Admissions Office. Typically, all of the work done towards a masters degree in the same field will apply toward satisfying the requirements for the Ph.D. Students who wish to transfer a masters degree in a different field should be prepared to provide course descriptions and/or syllabi to the GSC. The GSC will evaluate the student's transcripts and supporting documentation to determine how many credits should be transferred and which course requirements have been met by transfer courses.

The student's permanent adviser will help the student formulate an overall plan of study, including course work, reading, independent study and a plan of research. The program of study must include a total of 84 credit hours, of which up to 32 credit hours may be from a completed M.S. degree. Course work must account for a minimum of 36 credit hours, with a minimum of 16 credit hours beyond the M.S., and the remaining 24 to 48 credit hours must be research. Note that students cannot register for MMAE 691, Ph.D. Thesis Research until they have passed the Ph.D. qualifying exam.

In the following tables, see Section 4 for a list of pre-approved engineering analysis courses and core and elective courses in each major area. Also note that course and research credit hours taken during a M.S. degree apply towards meeting the Ph.D. requirements listed in the tables.

3.1.1 Degree Requirements for the Ph.D. in Mechanical and Aerospace Engineering

Engineering analysis courses	MMAE 501, MMAE 502 and two courses from group EA (12-14 credit hours)
Core course in major area	3-4 credit hours
Core course in second area	3-4 credit hours
Non-core courses in major area	Minimum of 9 credit hours
Thesis research	MMAE 591 (6-8 credits) and MMAE 691 (24-42 credits)
Remaining hours	Elective courses
Total	84 credit hours

Group EA: MMAE 503, MMAE 507, MMAE 508, MATH 512, MATH 515, MATH 522, MATH 535, MATH 544, MATH 545, MATH 553, ECE 511, ECE 531, ECE 537, ECE 567

Notes:

- Students specializing in fluid dynamics, thermal sciences, and solids and structures must take MMAE 507 as one of the courses in group EA.
- Care should be taken to be sure that all prerequisite requirements are fulfilled for the courses in Group EA (see section 4).
- Other engineering analysis courses may be substituted with approval of the advisor and Graduate Studies Committee; however, substitutions may not include primarily computational courses or courses with substantial overlap with other engineering analysis courses taken.

3.1.2 Degree Requirements for the Ph.D. in Materials Science and Engineering

Engineering analysis course:	MMAE 501 (3 credits)
MSE core courses	12 credits including: MMAE 563 MMAE 569 MMAE 468 or MMAE 486 MMAE 470, MMAE 579, or MMAE 580
Thesis research	MMAE 591 (6-8 credits) and MMAE 691 (24-42 credits)
Remaining hours	Elective courses
Total	84 credit hours

3.2 Ph.D. Qualifying Exam

Students who are admitted to the MMAE Ph.D. program must pass a qualifying examination administered by the department in order to be admitted to candidacy for the Ph.D. degree and be eligible to register for MMAE 691, Ph.D. Thesis Research. The examination evaluates the student's technical background in order to determine the student's potential for achieving a doctorate.

3.2.1 Ph.D. Qualifying Exam Procedures and Regulations

The Ph.D. qualifying exam for both MAE and MSE students is administered by the MMAE Ph.D. Qualifying Exam Committee. The exam is typically scheduled in each of the fall and spring semesters on the last Fridays of October and February, respectively. MMAE students who have been admitted to the Ph.D. program must take the qualifying exam no later than the third semester of full time study in the MMAE department. Students who have graduated from IIT with an MS degree and are subsequently admitted to the PhD program in the same field must take the qualifying exam during their first semester of study in the PhD program.

Students who wish to take the exam must register for the exam within the first two weeks of the semester in which they intend to take the exam. Students can access problems from previous exams and register for the exam on the MMAE web site. No other copies of past exams (electronic or hard copy) will be provided to students.

Each problem will be evaluated by two tenure track or tenured MMAE faculty members. The Ph.D. Qualifying Exam Committee then reviews these evaluations and makes a decision regarding the outcome of the exam. After this decision is made, the student will receive a letter from the Chair of the Ph.D. Qualifying Exam Committee that describes the outcome of the exam and provides information on what steps the student needs to take in the event that he/she does not pass. If a student does not pass the written exam, there are two possible outcomes: 1) The student may be required to take an oral exam on up to two subjects as recommended by the committee, or 2) The committee may recommend that the student retake the written exam the next semester that it is offered.

The oral exam is typically administered near the end of the semester in which the student took the written exam. The MMAE faculty who are appointed to administer the oral exam will be identified in the outcome letter received by the student. The results of the oral exam will be communicated to the Chair of the Ph.D. Qualifying Exam Committee. The Chair will then communicate the results to the student. If the student does not pass the oral exam, he/she may retake the written exam the next semester in which the exam is offered. If the student fails a second written exam, he/she may be required to take a second oral exam. If the student fails the second written and/or oral exam, he/she will not be permitted to continue in the MMAE Ph.D. program.

3.2.2 MAE Exam

The Ph.D. qualifying examination for MAE students consists of up to 12 problems. The problems are based on course material covered in the following courses:

- MMAE 501, Engineering Analysis 1b
- MMAE 502, Engineering Analyis II
- MMAE 510, Fundamentals of Fluid Mechanics
- MMAE 525, Fundamentals of Heat Transfer
- MMAE 530, Advanced Mechanics of Solids
- MMAE 541, Advanced Dynamics
- MMAE 545, Advanced CAD/CAM

Students are given one problem from MMAE 501, one from MMAE 502, and two problems from each of the remaining courses. Out of these 12 problems, the student must answer four as follows: one from engineering analysis, one from his/her major area, one from a second area, and one from any of the above areas. The exam is closed book, and the student is given five hours to complete the four problems. Based on the student's performance on the written exam, the Ph.D. Qualifying Exam Committee may decide to continue the exam in oral form towards the end of the semester.

3.2.3 MSE Exam

The Ph.D. qualifying examination for MSE students consists of 8 problems: two from Engineering Analysis (MMAE 501), two from Advanced Physical Metallurgy (MMAE 569), two from Advanced Mechanical Metallurgy (MMAE 563), two from the area of ceramics or two from the area of polymers. The student must answer one problem from each of the four areas. The student is given five hours to complete the four problems. Based on the student's performance on the written exam, the Ph.D. Qualifying Exam Committee may decide to continue the exam in oral form towards the end of the semester.

3.3 Thesis Research and Ph.D. Examinations

3.3.1 Ph.D. Advisory Committee

The purpose of the Thesis Advisory Committee is to assist the student in the satisfactory and timely progression of the thesis research and to evaluate the comprehensive and final oral examinations. The committee is nominated by the student's adviser and appointed by the GSC, using Form 301A, in preparation for the Comprehensive Exam. Upon approval by the GSC, Form 301A is submitted to the Graduate College. Ph.D. students should submit Form 301B prior to the final oral examination, i.e. the Ph.D. defense.

The MAE student's Ph.D. Advisory Committee must consist of at least four full-time IIT (tenured or tenure track) faculty members as follows:

- the student's adviser, who acts as committee chair
- one representative from the student's major area
- one representative from outside the student's major area but in the MAE program
- one representative from outside the MAE program

The Ph.D. Advisory Committee for MSE students must consist of at least four full-time IIT (tenured or tenure track) faculty members as follows:

- the student's adviser, who acts as committee chair
- two tenured or tenure-track professors of materials engineering
- one representative from outside the MSE program

Non-tenured or tenure-track IIT faculty, or scientists from outside IIT, may serve as additional non-voting committee members with approval of the GSC. Once the GSC approves the makeup of the Ph.D. Advisory Committee, the student must notify the Dean of the Graduate College of the comprehensive exam no later than two weeks prior to the exam date using Form 301A, Ph.D. Comprehensive Exam Committee and Exam Scheduling.

3.3.2 Ph.D. Comprehensive Exam

Whereas the purpose of the Ph.D. qualifying examination is to asses a student's technical background in the topical areas related to their degree program, the objective of the comprehensive examination is to determine the student's level of competency in conducting research in the area of his/her thesis. The comprehensive examination must be conducted at least one year before the Ph.D. defense examination.

The comprehensive exam consists of two components, a written and oral thesis proposal and a brief research report and presentation. The student must submit a brief written thesis proposal to the Ph.D. committee prior to the oral comprehensive examination. During the comprehensive examination, the student is expected to present his/her thesis proposal. The approval of the proposal will be based on a satisfactory oral presentation to the committee and evaluation of the written proposal.

In addition to the proposal, the Ph.D. Committee will provide the student with a research topic that the student is to investigate the current literature, assimilate the current methods and knowledge related to the topic, suggest novel improvements and approaches, and write a short report summarizing these issues. The topic of the written exam should be complementary to the students research area, but outside the scope of the student's dissertation research. The topic must be sufficiently narrow to be amenable to completion within an approximately two week time frame (including writing the report). The topic should be conveyed to the student with a short background of the topic, a reference(s) to use as a starting point, and some possible questions or issues to address.

The suggested Comprehensive Exam timeline is as follows:

1. Student submits written dissertation proposal to Ph.D. committee approximately two weeks prior to the oral exam.

2. Committee conveys written topic to student upon submission of the written proposal.

3. Student has approximately two weeks to research written topic and write a short report on his/her findings.

4. The written report is submitted to the committee members a couple of days prior to the oral exam.

5. Oral exam on written topic and dissertation proposal presentation. (At the committee's discretion, the oral exam on the written topic and the thesis proposal may be conducted on separate days).

The results of the Comprehensive Examination are reported to the Graduate College on Form 309 by the student's adviser in the presence of all members of the Comprehensive Examination Committee, and should be returned to the Dean of the Graduate College within 48 hours after the completion of the exam. Form 309 must be received no later than one week prior to the last day of classes.

3.3.3 Ph.D. Thesis Review and Defense Examination

The student files an Application for Graduation, Form 527, within two weeks of the start of the semester in which he/she expects to graduate. This application is valid only for the semester in which it is filed (including summer) and must be re-filed in the event that the student's graduation is delayed to a later semester. The student must be registered for a minimum of one credit hour in the semester in which they graduate (including summer).

A thesis preparation discussion is held early each semester to assist students in preparing their thesis and alerting them to problems that may occur. The Graduate College announces the exact date and time each semester. The MMAE student's thesis must conform to the guidelines given in the latest IIT Thesis Manual. The IIT Thesis Manual can be downloaded from the thesis information web site. Templates in Word and LaTeX formats are also available for download. The Thesis Examiner is the appointed expert available to the students for guidance in conforming to the requirements set out in the Thesis Manual.

The student's initial appointment with the Thesis Examiner must be made at least six weeks before the end of the anticipated graduation semester. To make an appointment with the thesis examiner, contact Pat Johnson-Winston at 312-567-3370 or winston@iit.edu.

The Dean of the Graduate College must be notified of the re-appointment of the committee and the date, time and place of the examination. Form 301B, Ph.D. Thesis Committee Final Oral Exam Scheduling must be submitted to the Dean of the Graduate College at least two weeks prior to the exam and five weeks prior to commencement.

Upon completion of the dissertation research, the student prepares a preliminary draft of his/her dissertation and submits copies to the Ph.D. Advisory Committee. The student obtains approval of the preliminary draft of the dissertation from the committee members, the Department Chair, and the Thesis Examiner (by prior appointment) on Form 501A, Preliminary Thesis Approval, at least 5 weeks before commencement and two weeks prior to the oral defense.

At least seven days prior to the final oral examination, the student distributes copies of the approved thesis draft to the thesis committee members. His/her adviser then emails all MMAE faculty members announcing the place and time of the examination. The email should include an abstract of the thesis. It is the student's responsibility to ensure that the email is sent on time. Failure to do so may result in rescheduling of the examination.

After the preliminary draft of the dissertation is approved, the student defends his/her dissertation at a final oral public examination.[1] The student's Ph.D. Advisory Committee conducts the final defense examination. The results of the Defense Examination are reported to the Graduate College on Form 309 by the student's adviser in the presence of all members of the Ph.D. Advisory Committee, and should be returned to the Dean of the Graduate College within 72 hours after the final oral exam and no later than one week prior to the last day of classes. Once the final thesis draft is approved by the committee on Form 501B, Final Thesis Approval, the student obtains his/her adviser's signature on the final draft of the dissertation and pays the advanced degree fee in the Bursar's office.

The student meets with the Thesis Examiner at least nine days before commencement for final dissertation approval (by prior appointment) with the following:

- Three copies of dissertation in separately labeled manila envelopes
- Bursar's receipt showing payment of fee
- Form 50lB bearing all approval signatures except the final Thesis Examiner's
- Two copies of dissertation abstract of less than 60 words in dissertation abstract style

[1] The Ph.D. final oral examination shall be open to the public without restriction. However, the committee appointed to conduct the examination may continue the defense and deliberate the candidate's performance and prepare its report in private.

- One copy of University Microfilms Agreement Form
- Two copies of the Survey of Earned Doctorates Form
- One separate title page

Note: The three thesis copies are bound and distributed to the library, the department archives, and the adviser. The Graduate College will not provide binding for more than three copies, but the student is urged to get his/her own private copy bound using IIT Office Services.

Chapter 4

MMAE Courses

4.1 Engineering Analysis Courses

The pre-approved engineering analysis courses are:

MMAE 501	Engineering Analysis I
MMAE 502	Engineering Analysis II
MMAE 503	Advanced Engineering Analysis
MMAE 507	Introduction to Continuum Mechanics
MMAE 508	Perturbation Methods
MATH 512	Partial Differential Equations
MATH 515	Ordinary Differential Equations and Dynamical Systems
MATH 522	Mathematical Modeling
MATH 535	Optimization I
MATH 544	Stochastic Dynamics
MATH 545	Stochastic Partial Differential Equations
MATH 553	Discrete Applied Mathematics I
ECE 511	Analysis of Random Signals
ECE 531	Linear Systems Theory
ECE 537	Optimal Feedback Control
ECE 567	Statistical Signal Processing

4.2 Courses Listed by Major Area

The MMAE graduate programs have six different areas of study: Fluid Dynamics, Thermal Sciences, Solids and Structures, Design and Manufacturing, Dynamics and Control, and Materials Science and Engineering. In this section, the core and non-core courses in each major area are listed in tabular form. The core course(s) in each area of study is marked in red italics.

4.2.1 Fluid Dynamics

MMAE 510	*Fundamentals of Fluid Mechanics*
MMAE 511	Compressible Flows
MMAE 512	Viscous Flows
MMAE 513	Turbulent Flows
MMAE 514	Stability of Viscous Flows
MMAE 515	Engineering Acoustics
MMAE 516	Advanced Experimental Methods in Fluids
MMAE 517	Computational Fluid Mechanics
MMAE 518	Spectral Methods in Computational Fluid Mechanics

Other relevant courses

MMAE 507	Introduction to Continuum Mechanics
MMAE 508	Perturbation Methods
MMAE 525	Fundamentals of Heat Transfer
MMAE 527	Heat Transfer: Convection and Radiation
CHE 536	Computational Techniques in Engineering
CHE 551	Fluid Dynamics

4.2.2 Thermal Sciences

MMAE 433	Design of Thermal Systems
MMAE 520	Advanced Thermodynamics
MMAE 521	Statistical Thermodynamics
MMAE 523	Fundamentals of Power Generation
MMAE 524	Fundamentals of Combustion
MMAE 525	*Fundamentals of Heat Transfer*
MMAE 526	Heat Transfer: Conduction
MMAE 527	Heat Transfer: Convection and Radiation
MMAE 528	Liquid-Vapor Phase-Change Phenomena

Other relevant courses

MMAE 507	Introduction to Continuum Mechanics
MMAE 508	Perturbation Methods
MMAE 510	Fundamentals of Fluid Mechanics
MMAE 512	Viscous Flows
MMAE 513	Turbulent Flows
MMAE 514	Stability of Viscous Flows
MMAE 516	Advanced Experimental Methods in Fluids
MMAE 517	Computational Fluid Mechanics
CHE 501	Transport Phenomena
CHE 503	Chemical Engineering Thermodynamics
CHE 505	Fluid Properties
CHE 512	Heat Transfer
CHE 518	Mass Transfer
CHE 542	Fluid and Gas-Solid Flow

4.2.3 Solids and Structures

MMAE 451/CAE 442	Finite Element Methods I
MMAE 529	Theory of Plasticity
MMAE 530	*Advanced Mechanics of Solids*
MMAE 531	Theory of Elasticity
MMAE 532/CAE 530	Finite Element Methods II
MMAE 533	Fatigue and Fracture Mechanics
MMAE 535	Design/Analysis of Brittle Structures
MMAE 536	Experimental Solid Mechanics
MMAE 538/CAE 534	Computational Techniques in FEM

Other relevant courses

MMAE 507	Introduction to Continuum Mechanics
MMAE 508	Perturbation Methods
MMAE 570	Computational Methods in Materials Processing
MMAE 578	Fiber Composites
CHE 580	Biomaterials

4.2.4 Computer-Aided Design and Manufacturing

MMAE 445	CAD/CAM with Numerical Control
MMAE 544	Design Optimization
MMAE 545	*Advanced CAD/CAM*
MMAE 546	Advanced Manufacturing Engineering
MMAE 547	Computer Integrated Manufacturing – Technologies
MMAE 548	Principles of Minimum Weight Design
MMAE 551	Experimental Mechatronics
MMAE 552	Practical Machine Design
MMAE 556	Nanoscale Imaging and Manipulation
MMAE 557	Computer Integrated Manufacturing – Systems
MMAE 560	Statistical Process and Quality Control
MMAE 577	Lasers in Manufacturing
MMAE 584	Forging and Forming
MMAE 589	Applications in Reliability Engineering I
MMAE 590	Applications in Reliability Engineering II

Other relevant courses

MMAE 433	Design of Thermal Systems
MMAE 540	Robotics
MMAE 551	Experimental Mechatronics

4.2.5 Dynamics and Control

MMAE 540	Robotics
MMAE 541	*Advanced Dynamics*
MMAE 543	Modern Control Systems
MMAE 551	Experimental Mechatronics
MMAE 555	Introduction to Navigation Systems

Other relevant courses

MMAE 508	Perturbation Methods
MMAE 544	Design Optimization
MMAE 560	Statistical Process and Quality Control
ECE 511	Analysis of Random Signals
ECE 513	Communication Engineering Fundamentals
ECE 531	Linear System Theory
ECE 535	Discrete Time Systems
ECE 537	Optimal Feedback Control
ECE 567	Statistical Signal Processing
ECE 569	Digital Signal Processing
BME 511	Physiological Control Systems and Modeling

4.2.6 Materials Science and Engineering

MMAE 468	*Introduction to Ceramic Materials*
MMAE 470	*Introduction to Polymer Science*
MMAE 486	*Properties of Ceramics*
MMAE 561	Solidification
MMAE 562	Design of Modern Alloys
MMAE 563	*Advanced Mechanical Metallurgy*
MMAE 564	Dislocation and Strength Mechanisms
MMAE 565	Preferred Orientations
MMAE 566	Problems in High Temperature Materials
MMAE 567	Fracture Mechanisms
MMAE 568	Diffusion
MMAE 569	*Advanced Physical Metallurgy*
MMAE 570	Computational Methods in Materials Processing
MMAE 571	Microstructural Characterization of Materials
MMAE 572	Gas-Metal Reactions
MMAE 573	Transmission Electron Microscopy
MMAE 574	Ferrous Transformations
MMAE 575	Ferrous Products: Met. and Manuf.
MMAE 576	Materials and Process Selection
MMAE 578	Fiber Composites
MMAE 579	*Characterization of Polymers*
MMAE 580	*Structure and Properties of Polymers*
MMAE 581	Theory and Mechanical Behavior of Polymers
MMAE 582	Ferrous Technology

Other relevant courses

MMAE 451	Finite Element Methods I
MMAE 525	Fundamentals of Heat Transfer
MMAE 530	Advanced Mechanics of Solids
MMAE 532	Finite Elements II
MMAE 533	Fatigue and Fracture Mechanics
MMAE 549	Tribology
MMAE 577	Lasers in Manufacturing
MMAE 584	Forming and Forging
CHE 580	Biomaterials

4.3 Graduate Course Schedule and Frequencies

The projected MMAE graduate course offerings are provided on the MMAE website to enable students to plan an appropriate course sequence throughout their degree program. These projections are tentative and subject to change.

4.4 Course Descriptions

4.4.1 Engineering Analysis

MMAE 501 Engineering Analysis I Vectors and matrices, systems of linear equations, linear transformations, eigenvalues and eigenvectors, systems of ordinary differential equations, decomposition of matrices, and functions of matrices. Eigenfunction expansions of differential equations, self-adjoint differential operators, Sturm-Liouville equations. Complex variables, analytic functions and Cauchy-Riemann equations, harmonic functions, conformal mapping, and boundary-value problems. Calculus of variations, Euler's equation, constrained functionals, Rayleigh-Ritz method, Hamilton's principle, optimization and control. Prerequisite: undergraduate course in differential equations. (3-0-3)

MMAE 502 Engineering Analysis II Generalized functions and Green's functions. Complex integration: series expansions of complex functions, singularities, Cauchy's residue theorem, and evaluation of real definite integrals. Integral transforms: Fourier and Laplace transforms, applications to partial differential equations and integral equations. Prerequisite: MMAE 501. (3-0-3)

MMAE 503 Advanced Engineering Analysis Selected topics in advanced engineering analysis, such as ordinary differential equations in the complex domain, partial differential equations, integral equations, and/or nonlinear dynamics and bifurcation theory, chosen according to student and instructor interest. Prerequisite: MMAE 502. (3-0-3)

MMAE 507 Introduction to Continuum Mechanics A unified treatment of those topics are common to solid and fluid continua. General discussion of Cartesian tensors. Deformation, strain, strain invariants, rotation, compatibility conditions. Motion, velocity, deformation. Momentum, moment of momentum, energy, stress. Principles of balance of local momenta, equations of motion. Principles of frame indifference. Constitutive relations for fluids, elastic and plastic solids. Concurrent Prerequisite: MMAE 501. (4-0-4)

MMAE 508 Perturbation Methods Asymptotic series, regular and singular perturbations, matched asymptotic expansions, and WKB theory. Methods of strained coordinates and multiple scales. Application of asymptotic methods in science and engineering. Prerequisite: MMAE 501. (3-0-3)

4.4.2 Fluid Dynamics

MMAE 510 Fundamentals of Fluid Mechanics Kinematics of fluid motion. Constitutive equations of isotropic viscous compressible fluids. Derivation of Navier-Stokes equations. Lessons from special exact solutions, self-similarity. Admissibility of idealizations and their applications; inviscid, adiabatic, irrotational, incompressible, boundary- layer, quasi one-dimensional, linearized and creeping flows. Vorticity theorems. Unsteady Bernoulli equation. Basic flow solutions. Basic features of turbulent flows. Concurrent Prerequisite: MMAE 501. (4-0-4)

MMAE 511 Dynamics of Compressible Fluids Low-speed compressible flow past bodies. Linearized, subsonic, and supersonic flow past slender bodies. Similarity laws. Transonic flow. Hypersonic flow, mathematical theory of characteristics. Applications including shock and nonlinear wave interaction in unsteady one-dimensional flow and two-dimensional, planar and axisymmetric supersonic flow. Prerequisite: MMAE 510. (3-0-3)

MMAE 512 Dynamics of Viscous Fluids Navier-Stokes equations and some simple exact solutions. Oseen-Stokes flows. Boundary-layer equations and their physical interpretations. Flows along walls and in channels. Jets and wakes. Separation and transition to turbulence. Boundary layers in unsteady flows. Thermal and compressible boundary layers. Mathematical techniques of similarity transformation, regular and singular perturbation, and finite differences. Prerequisite: MMAE 510. (4-0-4)

MMAE 513 Turbulent Flows Stationary random functions. Correlation tensors. Wave number space. Mechanics of turbulence. Energy spectrum. Dissipation and energy cascade. Turbulence measurements. Isotropic turbulence. Turbulent transport processes. Mixing and free turbulence. Wall-constrained turbulence. Compressibility effects. Sound and pseudo-sound generated by turbulence. Familiarity with basic concepts of probability and statistics and with Cartesian tensors is assumed. Prerequisite: MMAE 510. (4-0-4)

MMAE 514 Stability of Viscous Flows Concept of hydrodynamic stability. Governing equations. Analytical and numerical treatment of eigenvalue problems and variational methods. Inviscid stability of parallel flows and spiral flows. Thermal instability and its consequences. Stability of channel flows, layered fluid flows, jets and flows around cylinders. Other effects and their consequences; moving frames, compressibility, stratification, hydromagnetics. Nonlinear theory and energy methods. Transition to turbulence. Prerequisites: MMAE 502, MMAE 510. (4-0-4)

MMAE 515 Engineering Acoustics Characteristics of sound waves in two and three dimensions. External and internal sound wave propagation. Transmission and reflection of sound waves through media. Sources of sound from fixed and moving bodies. Flow-induced vibrations. Sound-level measurement techniques. (3-0-3)

MMAE 516 Advanced Experimental Methods in Fluid Mechanics Design and use of multiple sensor probes to measure multiple velocity components, reverse-flow velocities, Reynolds stress, vorticity components and intermittency. Simultaneous measurement of velocity and temperature. Theory and use of optical transducers, including laser velocimetry and particle tracking. Special measurement techniques applied to multiphase and reacting flows. Laboratory measurements in transitional and turbulent wakes, free-shear flows, jets, grid turbulence and boundary layers. Digital signal acquisition and processing. Prerequisite: Instructor's consent. (2-3-3)

MMAE 517 Computational Fluid Dynamics Classification of partial differential equations. Finite-difference methods. Numerical solution techniques, including direct, iterative and multigrid methods, for general elliptic and parabolic differential equations. Numerical algorithms for solution of the Navier-Stokes equations in the primitive-variables and vorticity-streamfunction formulations. Grids and grid generation. Numerical modeling of turbulent flows. Prerequisites: MMAE 510 and undergraduate course in numerical methods. (3-0-3)

MMAE 518 Spectral Methods in Computational Fluid Dynamics Application of advanced numerical methods and techniques to the solution of important classes of problems in fluid mechanics. Emphasis is in methods derived from weighted-residuals approaches, like Galerkin and Galerkin-Tau methods, spectral and pseudo-spectral methods, and dynamical systems modeling via projections on arbitrary orthogonal function bases. Finite element and spectral element methods will be introduced briefly in the context of Galerkin methods. A subsection of the course will be devoted to numerical turbulence modeling, and to the problem of grid generation for complex geometries. Prerequisites: MMAE 501 and MMAE 510. (3-0-3)

4.4.3 Thermal Sciences

MMAE 433 Design of Thermal Systems Application of principles of fluid mechanics, heat transfer, and thermodynamics to design of components of engineering systems. Examples are drawn from power generation, environmental control, air and ground transportation, and industrial processes, as well as other industries. Groups of students work on projects for integration of these components and design of thermal systems. Prerequisites: MMAE 321, MMAE 322. (2-3-3) (C)

MMAE 520 Advanced Thermodynamics Macroscopic thermodynamics: first and second laws applied to equilibrium in multicomponent systems with chemical reaction and phase change; availability analysis; evaluations of thermodynamic properties of solids, liquids; and gases for single and multicomponent systems. Applications to contemporary engineering systems. Prerequisite: Undergraduate course in applied thermodynamics. (3-0-3)

MMAE 521 Statistical Thermodynamics Nature of statistical thermodynamics, kinetic description of dilute gases. Elementary kinetic theory of transport processes. Classical statistics of independent particles. Development of quantum mechanics. Application of quantum mechanics. Quantum statistics and thermostatic properties of ideal gases. Prerequisite: Undergraduate course in applied thermodynamics or instructor's consent. (3-0-3)

MMAE 523 Fundamentals of Power Generation Thermodynamic, combustion, and heat transfer analyses relating to steam-turbine and gas-turbine power generation. Environmental impacts of combustion power cycles. Consideration of alternative and sustainable power generation processes such as wind and tidal, geothermal, hydroelectric, solar, fuel cells, nuclear power, and microbial. (3-0-3)

MMAE 524 Fundamentals of Combustion Combustion stoichiometry. Chemical equilibrium. Adiabatic flame temperature. Reaction kinetics. Transport processes. Gas flames classification. Premixed flames. Laminar and turbulent regimes. Flame propagation. Deflagrations and detonations. Diffusion flames. Spray combustion. The fractal geometry of flames. Ignition theory. Pollutant formation. Engine combustion. Solid phase combustion. Combustion diagnostics. Prerequisite: Undergraduate courses in applied thermodynamics and heat transfer or instructor's consent. (3-0-3)

MMAE 525 Fundamentals of Heat Transfer Modes and fundamental laws of heat transfer. The heat equations and their initial and boundary conditions. Conduction problems solved by separation of variables. Numerical methods in conduction. Forced and natural convection in channels and over exterior surfaces. Similarity and dimensionless parameters. Heat and mass analogy. Effects of turbulence. Boiling and condensation. Radiation processes and properties. Blackbody and gray surfaces radiation. Shape factors. Radiation shields. Prerequisite: Undergraduate course in heat transfer. (3-0-3)

MMAE 526 Heat Transfer: Conduction Fundamental laws of heat conduction. Heat equations and their initial and boundary conditions. Steady, unsteady and periodic states in one or multidimensional problems. Composite materials. Methods of Greens functions, eigenfunction expansions, finite differences, finite element methods. Prerequisites: MMAE 502, MMAE 525. (3-0-3)

MMAE 527 Heat Transfer: Convection and Radiation Convective heat transfer analyses of external and internal flows. Forced and free convection. Dimensional analysis. Phase change. Heat and mass analogy. Reynolds analogy. Turbulence effects. Heat exchangers, regenerators. Basic laws of radiation heat transfer. Thermal radiation and quantum mechanics pyrometry. Infrared measuring techniques. Prerequisite: MMAE 525. (3-0-3)

MMAE 528 Liquid-Vapor Phase-Change Phenomena This course focuses on basic elements of condensation and vaporization processes. Specifically, this course covers the thermodynamic and mechanical aspects of interfacial phenomena and phase transitions, boiling and condensation near immersed bodies, and internal flow convective boiling and condensation. Prerequisite: MMAE 525 and MMAE 510 or instructor's consent. (3-0-3)

4.4.4 Solids and Structures

MMAE 451 Finite Element Methods in Engineering This course provides a comprehensive overview of the theory and practice of the finite element method by combining lectures with selected laboratory experiences. Lectures cover the fundamentals of linear finite element analysis with special emphasis on problems in solid mechanics and heat transfer. Topics include the direct stiffness method, the Galerkin method, isoparametric finite elements, numerical integration, development of finite element equations, equation solvers, bandwidth of linear algebraic equations, and other computational issues. Lab sessions provide experience solving practical engineering problems using commercial finite element software. Special emphasis is given to mesh design and results interpretation using commercially available pre and post-processing software. Prerequisite: MMAE 304 or MMAE 306. (3-0-3)

MMAE 529 Theory of Plasticity Phenomenological nature of metals, yield criteria for 3-D states of stress, geometric representation of the yield surface. Levy-Mises and Prandtl- Reuss equations, associated and nonassociated flow rules, Druckers stability postulate and its consequences, consistency condition for nonhardening materials, strain hardening postulates. Elasticplastic boundary value problems. Computational techniques for treatment of small and finite plastic deformations. Prerequisite: MMAE 530. (3-0-3). Same as CAE 588. (3-0-3)

MMAE 530 Advanced Mechanics of Solids Analysis of stress and strain. Stress-strain relations. Twodimensional problems in elasticity. Axisymmetrically loaded thickwalled cylinders and rotating disks. Plates and axisymmetrical shells. Energy methods. Torsion. Beams on elastic foundations. Unsymmetric bending of straight beams. Prerequisites: Undergraduate course in mechanics of solids. Concurrent Prerequisite: MMAE 501. (3-0-3)

MMAE 531 Theory of Elasticity Notions of stress and strain, field equations of linearized elasticity. Plane problems in rectangular and polar coordinates. Problems without a characteristic length. Plane problems in linear elastic fracture mechanics. Complex variable techniques, energy theorems, approximate numerical techniques. Prerequisite: MMAE 530. (4-0-4)

MMAE 532 Finite Element Methods II Continuation of MMAE451/CAE442. Covers the theory and practice of advanced finite element procedures. Topics include implicit and explicit time integration, stability of integration algorithms, unsteady heat conduction, treatment of plates and shells, small-strain plasticity, and treatment geometric nonlinearity. Practical engineering problems in solid mechanics and heat transfer are solved using MATLAB and commercial finite element software. Special emphasis is placed on proper time step and convergence tolerance selection, mesh design, and results interpretation. Prerequisite: MMAE 451/CAE 442. (3-0-3)

MMAE 533 Fatigue and Fracture Mechanics Analysis of the general state of stress and strain in solids; dynamic fracture tests (FAD, CAT). Linear elastic fracture mechanics (LEFM), Griffith- Irwin analysis, ASTM KIC, KIPCI, KIA, KID. Plane stress, plane strain; yielding fracture mechanics (COD, JIC). Fatigue crack initiation. Goodman diagrams and fatigue crack propagation. Notch sensitivity and stress concentrations. Low-cycle fatigue, corrosion and thermal fatigue. Prerequisite: Undergraduate course in mechanics of solids. (3-0-3)

MMAE 535 Design and Analysis of Brittle Structures Analysis algorithm based on statistical fracture theory. Introduction to both conventional and extreme value statistics, combined stress theory, load redistribution models, and specimen testing and design. Design philosophies including structural reliability theory, destructive proof testing, and prestressing and segmenting. Applications to static design, thermal shock, and fragmentation of structures such as ceramic nose cones, leading edges and machine tools. Prerequisite: Undergraduate course in mechanics of solids. (3-0-3)

MMAE 536 Experimental Solid Mechanics Review of applied elasticity. Stress, strain and stress-strain relations. Basic equations and boundary value problems in plane elasticity. Methods of strain measurement and related instrumentation. Electrical resistance strain gauges, strain gauge circuits and recording instruments. Analysis of strain gauge data. Brittle coatings. Photoelasticity; photoelastic coatings; moire methods; interferometric methods. Applications of these methods in the laboratory. Prerequisite: Undergraduate course in mechanics of solids. (3-2-4)

MMAE 538/CAE 534 Computational Techniques in Finite Element Methods Survey of numerical methods as applied to FEM software. Database management, equation solvers, eigenvalue routines and schemes for direct integration (both implicit/ explicit), all as employed in the development of a finite element program. Topics also covered include band and front minimizer, static and dynamic substructuring via superelements, and sensitivity studies. Same as CAE 534. Prerequisite: MMAE 451 or CAE 442. (3-0-3)

4.4.5 Dynamics and Controls

MMAE 540 Robotics Kinematics and inverse kinematics of manipulators. NewtonEuler dynamic formulation. Independent joint control. Trajectory and path planning using potential fields and probabilistic roadmaps. Adaptive control. Force control. Prerequisite: MMAE 443 or equivalent. Concurrent Prerequisite: MMAE 501. (3-0-3)

MMAE 541 Advanced Dynamics Kinematics of rigid bodies. Rotating reference frames and coordinate transformations; Inertia dyadic. Newton-Euler equations of motion. Gyroscopic motion. Conservative forces and potential functions. Generalized coordinates and generalized forces. Lagranges equations. Holonomic and nonholonomic constraints. Lagrange multipliers. Kanes equations. Elements of orbital and spacecraft dynamics. Prerequisite: Undergraduate course in dynamics. Concurrent Prerequisite: MMAE 501. (3-0-3)

MMAE 543 Modern Control Systems Review of classical control. Discrete-time systems. Linear difference equations. Z-transform. Design of digital controllers using transform methods. State-space representations of continuous and discrete-time systems. State-feedback. Controllability and observability. Pole placement. Optimal control. Linear-Quadratic Regulator (LQR). Probability and stochastic processes. Optimal estimation. Kalman Filter. Prerequisite: Undergraduate course in classical control. Concurrent Prerequisite: MMAE 501 (3-0-3)

MMAE 551 Experimental Mechatronics Team based project. Microprocessor controlled electromechanical systems. Sensor and actuator integration. Basic analog and digital circuit design. Limited enrollment. Prerequisite: MMAE 443 or equivalent. (2-3-3)

MMAE 555 Introduction to Navigation Systems Fundamental concepts of positioning and dead reckoning. Principles of modern satellite-based navigation systems, including GPS, GLONASS, and Galileo. Differential GPS (DGPS) and augmentation systems. Carrier phase positioning and cycle ambiguity resolution algorithms. Autonomous integrity monitoring. Introduction to optimal estimation, Kalman filters, and covariance analysis. Inertial sensors and integrated navigation systems. Prerequisite: MMAE 443 or equivalent. Concurrent Prerequisite: MMAE 501. (3-0-3)

4.4.6 Design and Manufacturing

MMAE 445 CAD/CAM with Numerical Control Computer graphics in engineering design, computational geometry, and CAD software and hardware. Numerical control of machine tools by various methods. Prerequisite: CS 105, MATH 252. (3-0-3)

MMAE 544 Design Optimization Optimization theory and practice with examples. Finite-dimensional unconstrained and constrained optimization, Kuhn-Tucker theory, linear and quadratic programming, penalty methods, direct methods, approximation techniques, duality. Formulation and computer solution of design optimization problems in structures, manufacturing and thermofluid systems. Prerequisite: Undergraduate course in numerical methods. (3-0-3)

MMAE 545 Advanced CAD/CAM Interactive computer graphics in mechanical engineering design and manufacturing. Mathematics of three-dimensional object and curved surface representations. Surface versus solid modeling methods. Numerical control of machine tools and factory automation. Applications using commercial CAD/CAM in design projects. Prerequisite: MMAE 445 or instructor's consent. (3-0-3)

MMAE 546 Advanced Manufacturing Engineering Introduction to advanced manufacturing processes, such as powder metallurgy, joining and assembly, grinding, water jet cutting, laser-based manufacturing, etc. Effects of variables on the quality of manufactured products. Process and parameter selection. Important physical mechanisms in manufacturing process. Prerequisite: Undergraduate course in manufacturing processes or instructor's consent. (3-0-3)

MMAE 547 Computer-Integrated Manufacturing – Technologies The use of computer systems in planning and controlling the manufacturing process including product design, production planning, production control, production processes, quality control, production equipment and plant facilities. (3-0-3)

MMAE 548 Principles of Minimum-Weight Design Minimum weight designs of basic structural elements are developed for different behavior criteria including stiffness, elastic and plastic strength, and stability. A number of optimization techniques are used to explore various structural concepts, such as prestressing, statistical screening and energized systems. Prerequisite: Undergraduate course in mechanics of solids. Concurrent Prerequisite: MMAE 530. (3-0-3)

MMAE 549 Tribology Surface topography and integrity. Sliding and rolling friction. Temperature in sliding contact. Types, mechanisms, and theories of wear. Antifriction and wear-resistant materials. Boundary, hydrodynamic and elastohydrodynamic lubrication. High pressure and wear-resistant additives. Solid lubricants. Examples of tribology applied to engineering design. Prerequisite: Instructors consent. (3-0-3)

MMAE 552 Practical Machine Design This course includes an introduction to Precision Engineering, Synthesis of Mechanics, and Case Studies in Engineering Design. This group of topics introduces the theory and practical techniques of machine design. Methods for achieving precision and for linkage design are used in nearly all mechanical industries. The series of cases provide study of actual engineering practice, and include applications of gearing, bearings, shifts and linkage analysis with consideration of economics and patents. (3-0-3)

MMAE 556 Nanoscale Imaging and Manipulation This course provides an overview of methods for imaging and manipulating objects of the nanometer length scale. It introduces the basic principles of scanning probe microscopies (SPM), including scanning tunneling microscopy, atomic force microscopy (AFM), near field optical microscopy, and other scanning probe techniques. It further describes critical issues in SPM based nanoscale imaging and manipulation. On nanoscale imaging, it includes algorithms for surface reconstruction in SPM imaging and methods for high-speed AFM imaging. On nanoscale manipulation, it covers state-of-the-art manipulation techniques to create nanostructures, nanoscale physics, and manipulation planning. Prerequisite: Instructor's consent. (3-0-3)

MMAE 557 Computer Integrated Manufacturing – Systems Advanced topics in computer-integrated manufacturing, including control systems, group technology, cellular manufacturing, flexible manufacturing systems, automated inspection, lean production, just-in-time production, and agile manufacturing systems. (3-0-3)

MMAE 560 Statistical Process and Quality Control Basic theory, methods and techniques of on-line, feedback quality control systems for variable and attribute characteristics. Methods for improving the parameters of the production, diagnosis, and adjustment processes so that quality loss is minimized. Same as CHE 560. (3-0-3)

MMAE 589 Applications in Reliability Engineering I This first part of a two-course sequence focuses on the primary building blocks that enable an engineer to effectively communicate and contribute as a part of a reliability engineering effort. Students develop an understanding of the long term and intermediate goals of a reliability program and acquire the necessary knowledge and tools to meet these goals. The concepts of both probabilistic and deterministic design are presented, along with the necessary supporting understanding that enables engineers to make design trade-offs that achieve a positive impact on the design process. Strengthening their ability to contribute in a cross functional environment, students gain insight that helps them understand the reliability engineering implications associated with a given design objective, and the customers expectations associated with the individual product or product platforms that integrate the design. These expectations are transformed into metrics against which the design can be measured. A group project focuses on selecting a system, developing a flexible reliability model, and applying assessment techniques that suggest options for improving the design of the system. (3-0-3)

MMAE 590 Applications in Reliability Engineering II This is the second part of a twocourse sequence emphasizing the importance of positively impacting reliability during the design phase and the implications of not making reliability an integrated engineering function. Much of the subject matter is designed to allow the students to understand the risks associated with a design and provide the insight to reduce these risks to an acceptable level. The student gains an understanding of the methods available to measure reliability metrics and develops an appreciation for the impact manufacturing can have on product performance if careful attention is not paid to the influencing factors early in the development process. The discipline of software reliability is introduced, as well as the influence that maintainability has on performance reliability. The sequence culminates in an exhaustive review of the lesson plans in a way that empowers practicing or future engineers to implement their acquired knowledge in a variety of functional environments, organizations and industries. The group project for this class is a continuation of the previous course, with an emphasis on applying the tools and techniques introduced during this second of two courses. (3-0-3)

4.4.7 Materials Science and Engineering

MMAE 468 Introduction to Ceramic Materials The structure and structure/properties relationships of ceramic materials. Topics include: crystal structure types; crystal defects; structure of glass; phase equilibria and how these affect applications for mechanical properties; electrical properties; and magnetic properties. Sintering and ceramic reactions are related to microstructure resultant properties. Prerequisite: MS 201. (3-0-3)

MMAE 470 Introduction to Polymer Science An introduction to the basic principles that govern the synthesis, processing and properties of polymeric materials. Topics include classifications, synthesis methods, physical and chemical behavior, characterization methods, processing technologies and applications. Prerequisite: CHEM 124, MATH 251, PHYS 221. Same as CHE 470 and CHEM 470. (3-0-3) (C)

MMAE 475 Powder Metallurgy Production, pressing and sintering of metal powders. Effects of particle size, friction and die design on pressed densities. Theories of sintering. Relation of sintering practice to physical properties. Homogenization of alloys. Industrial equipment. Applications. Laboratory simulation of a series of P/M manufacturing cycles from powder to finished product are used to reinforce the classwork. Prerequisite: MMAE 361, MMAE 365. (2-3-3) (C)

MMAE 486 Properties of Ceramics Thermal, optical, mechanical, electrical and magnetic properties of ceramics and their applications. Includes a review of defect equilibria and ceramic microstructures. Prerequisites: MS 201,

MMAE 361, MMAE 365. (3-0-3)

MMAE 561 Solidification Properties of liquids, undercooling, solidification of single- and polyphase alloys, zone processes, controlled and directional solidification reactions. Prerequisite: Background in crystal structure and thermodynamics. (2-0-2)

MMAE 562 Design of Modern Alloys Phase rule, multicomponent equilibrium diagrams, determination of phase equilibria, parameters of alloy development, prediction of structure and properties. Prerequisite: Background in phase diagrams and thermodynamics. (2-0-2)

MMAE 563 Advanced Mechanical Metallurgy Analysis of the general state of stress and strain in solids. Analysis of elasticity, plasticity and fracture, with a major emphasis on the relationship between properties and structure. Isotropic and anisotropic yield criteria. Testing and forming techniques related to creep and superplasticity. Deformation mechanism maps. Fracture mechanics topics related to testing and prediction of service performance. Static loading to onset of rapid fracture, environmentally assisted cracking fatigue, and corrosion fatigue. Prerequisite: Background in mechanical properties. (3-0-3)

MMAE 564 Dislocations and Strengthening Mechanisms Basic characteristics of dislocations in crystalline materials. Dislocations and slip phenomena. Application of dislocation theory to strengthening mechanisms. Strain hardening. Solid solution and particle strengthening. Dislocations and grain boundaries. Grain size strengthening. Creep. Fatigue. Prerequisite: Background in materials analysis. (3-0-3)

MMAE 565 Materials Laboratory II Advanced synthesis projects studying microstructure and properties of a series of binary and ternary alloys. Gain hands-on knowledge of materials processing and advanced materials characterization through an integrated series of experiments to develop understanding of the processing–microstructure-properties relationship. Students arc melt a series of alloys, examine the cast microstructures as a function of composition using optical and electron microscopy, DTA, EDS, and XRD. The alloys are treated in different thermal and mechanical processes. The microstructural and mechanical properties modification and changes during these processes are characterized. Groups of students will be assigned different alloy systems, and each group will present their results orally to the class and the final presentation to the whole materials science and engineering group. (1-6-3)

MMAE 566 Problems in High-Temperature Materials Temperature-dependent mechanical properties. Creep mechanisms. Basic concepts in designing high-temperature materials. Metallurgy of basic alloy systems. Surface stability. High-temperature oxidation. Hot corrosion. Coatings and protection. Elements of process metallurgy. Prerequisite: Background in mechanical properties, crystal defects and thermodynamics. (3-0-3)

MMAE 567 Fracture Mechanisms Basic mechanisms of fracture and embrittlement of metals. Crack initiation and propagation by cleavage, microvoid coalescence, and fatigue mechanisms. Hydrogen embrittlement, stress corrosion cracking and liquid metal embrittlement. Temper brittleness and related topics. Prerequisite: Background in crystal structure, defects and mechanical properties. (3-0-3)

MMAE 568 Diffusion Theory Techniques and interpretation of diffusion studies in metals. Prerequisite: Background in crystal structure, defects and thermodynamics. (2-0-2)

MMAE 569 Advanced Physical Metallurgy Thermodynamics and kinetics of phase transformations, theory of nucleation and growth, metastability, phase diagrams. Prerequisite: Background in phase diagrams and thermodynamics. (3-0-3)

MMAE 570 Computational Methods in Materials Processing Advanced theories and computational methods used in understanding and modeling of various materials processing that involve deformation, solidification, microstructural changes, etc. This course will discuss the fundamental theories and mathematical models that describe the relevant physical phenomena in the computational framework of the finite element method. It will consist of three parts: (1) Lectures on fundamental theories and models, (2) computational and numerical methods, and (3) computer laboratories. Prerequisite: Background in finite-element methods and materials processing. (3-0-3)

MMAE 571 Microstructural Characterization of Materials Advanced optical microscopy. Scanning and transmission electron microscopies. x-ray microanalysis. Surface characterization. Quantitative microscopy. Elements of applied statistics. (2-3-3)

MMAE 572 Gas-Metal Reactions in the Surface Treatment of Steels Theory of solid and gas carburizing, nitriding, and carbonitriding. Generation of exothermic, endothermic and special gas atmospheres; control of atmosphere carburizing potential by dew point and infrared detectors. Prerequisite: Background in crystal structure and thermodynamics. (2-0-2)

MMAE 573 Transmission Electron Microscopy Design, construction and operation of transmission electron microscope, including image formation and principles of defect analysis in materials science applications. Theory and use of state-of-the-art microcharacterization techniques for morphological, crystallographic, and elemental analysis at high spatial resolutions at 10 nanometers in metallurgical and ceramic studies will also be covered. (2-3-3)

MMAE 574 Ferrous Transformations Allotropic modifications in iron and the solid solution effects of the important alloying elements on iron. Physical metallurgy of pearlite, bainite and martensite reactions. Physical and mechanical property changes during eutectoid decomposition and tempering. Prerequisite: Background in phase diagrams and thermodynamics. (3-0-3)

MMAE 575 Ferrous Products Metallurgy and Manufacture Relationships between the engineering properties of steels and the fundamental aspects of steelmaking and shaping technologies. Topics will include the behavior of high purity iron; effects of interstitial and substitutional alloying additions; metallurgical principles of strength, ductility and toughness; steelmaking and solidification; post-solidification processing; and micro-structure and crystallographic anisotropy. Prerequisite: Background in phase diagrams, phase transformations and thermodynamics. (3-0-3)

MMAE 576 Materials and Process Selection Context of selection; decision analysis; demand, materials and processing profiles; design criteria; selection schemes; value and performance oriented selection; case studies. (3-0-3)

MMAE 577 Lasers in Manufacturing Lasers and components of laser systems. Applications of lasers in manufacturing processes, including thermal treatment, drilling, cutting, turning, milling, welding and prototyping. (3-0-3)

MMAE 578 Fiber Composite Materials Structure and methods of preparation of fibers and fiber-reinforced composites. Micromechanics of fiber and particle reinforced composites. Prediction of elastic constants and strength. Stress analysis. Interfacial mechanics and properties. Prerequisite: Background in polymer synthesis and properties. (3-0-3)

MMAE 579 Characterization of Polymers Review of principles and practical applications of techniques for characterization of polymeric materials. Includes discussion of microscopy, diffraction and scattering methods, spectroscopy, thermal analysis, mechanical property measurements, trace analysis methods and rheological techniques. Prerequisite: Background in polymer synthesis and properties. (3-0-3)

MMAE 580 Structure and Properties of Polymers Molecular structure of amorphous, crystalline, and network polymers. Theories of the glassy state. Transition and melt temperatures. Model prediction of viscoelastic properties. Time-temperature superposition principle. Theory of rubber elasticity. Prerequisite: Background in polymer synthesis and properties. (3-0-3)

MMAE 581 Theory of Mechanical Behavior of Polymers Molecular theories for glass transitions and viscoelastic properties, strength of rubbery and glassy polymers. Deformation of crystalline polymers. Yield phenomena in glassy polymers. Photo-elastic properties of polymers. Prerequisite: Background in polymer synthesis and properties. (2-0-2)

MMAE 582 Ferrous Technology Production of ferrous materials in the steel mill, including treatment of the iron blast furnace and steel making in basic oxygen and electric-arc furnace. Processing of the materials in the plant and thermodynamic reaction considerations. Emerging processes will also be discussed. (3-0-3)

MMAE 584 Forging and Forming Mechanical and metallurgical basis for successful production of forgings and stampings. Prerequisite: Background in materials processing and analysis. (3-0-3)

4.4.8 Research, Seminar, Special Topics and Project Courses

MMAE 591 Research and Thesis for M.S. Degree

MMAE 593 Seminar Reports on current research. Fulltime graduate students in the department are required to register and attend.(1-0-0)

MMAE 594 Project for Professional Master Students Design projects for the Master of Mechanical and Aerospace Engineering, Master of Metallurgical and Materials Engineering, and Master of Manufacturing Engineering degrees. (Variable credit.)

MMAE 597 Special Topics Advanced topics in the fields of mechanics, mechanical and aerospace, metallurgical and materials, and manufacturing engineering in which there is special student and staff interest. (Variable credit.)

MMAE 691 Research and Thesis for Ph.D. Degree

4.4.9 Accelerated Courses

MMAE 704 Introduction to Finite-Element Analysis This course provides a comprehensive overview of the theory and practice of the finite element method by combining lectures with selected laboratory experiences. Lectures cover the fundamentals of linear finite element analysis, with special emphasis on problems in solid mechanics and heat transfer. Topics include the direct stiffness method, the Galerkin method, isoparametric finite elements, numerical integration, development of finite element equations, equation solvers, bandwidth of linear algebraic equations and other computational issues. Lab sessions provide experience in solving practical engineering problems using commercial finite element software. Special emphasis is given to mesh design and results interpretation using commercially available pre-and post-processing software. Note: This course is offered as an intersession short course. (2-0-2)

MMAE 705 Computer-Aided Design with Pro/ENGINEER This course provides an introduction to computer-aided design and an associated finite element analysis technique. A series of exercises and instruction in Pro/ENGINEER will be completed. The operation of Mecanica (the associated FEM package) will also be introduced. Previous experience with CAD and FEA will definitely speed learning, but is not essential. Note: This course is offered as an intersession course. (2-0-2)

MMAE 709 Overview of Reliability Engineering This course covers the role of reliability in robust product design. It dwells upon typical failure mode investigation and develops strategies to design them out of the product. Topics addressed include reliability concepts, systems reliability, modeling techniques, and system availability predications. Case studies are presented to illustrate the cost-benifits due to pro-active reliability input to systems design, manufacturing, and testing. (2-0-2)

MMAE 710 Dynamic and Nonlinear Finite Element Analysis Provides a comprehensive understanding of the theory and practice of advanced finite element procedures. The course combines lectures on dynamic and nonlinear finite element analysis with selected computer labs. The lectures cover implicit and explicit time integration techniques, stability of integration algorithms, treatment of material and geometric nonlinearity, and solution techniques for nonlinear finite element equations. The computer labs train students to solve practical engineering problems in solid mechanics and heat transfer using ABAQUS and Hypermesh. Special emphasis is placed on proper time step and convergence tolerance selection, mesh design, and results interpretation. A full set of course notes will be provided to class participants as well as a CD-ROM containing course notes, written exercies, computer labs, and all worked out examples. Prerequisite: MMAE 704 or equivalent or consent of instructor. Note: This course is offered as an intersession short course. (2-0-2)

MMAE 713 Engineering Economic Analysis Introduction to the concepts of Engineering Economic Analysis, also known as micro-economics. Topics include equivalence, the time value of money, selecting between alternatives, rate of return analysis, compound interest, inflation, depreciation, and estimating economic life of an asset. (2-0-2)

MMAE 715 Project Management This course covers the basic theory and practice of project management from a practical viewpoint. Topics include project management concepts, resources, duration vs. effort, project planning and initiation, progress tracking methods, CPM and PERT, reporting methods, replanning, team project concepts, and managing multiple projects. Microsoft Project software will be used extensively. (2-0-2)

MMAE 720 Design Assurance This course covers a range of analytical and procedural methods which support product and process development. Also referred to as Six Sigma, this approach ensures a more effective product by defining design requirements based on a comprehensive examination of the circumstances of the application. The methodology includes the use of such techniques as time line analysis, cause and effect analysis, failure mode analysis and Taguchi's robust design approach. Additionally, the importance of developmental testing is emphasized. (2-0-2)

MMAE 723 Discrete Event Simulation Introduction to purposes, tools and concepts of Discrete Event Simulation with particular emphasis on simulation of production systems for the manufacturing and services sectors. Focus will be on theory and application rather than specific software packages, although one program will be used as an example. (2-0-2)

4.4.10 Relevant Courses in Applied Mathematics

MATH 512 Partial Differential Equations Basic model equations describing wave propagation, diffusion and potential functions; characteristics, Fourier transform, Green function, and eigenfunction expansions; elementary theory of partial differential equations; Sobolev spaces; linear elliptic equations; energy methods; semigroup methods; applications to partial differential equations from engineering and science. Prerequisites: MATH 461 or MATH 489 or consent of the instructor. (3-0-3)

MATH 515 Ordinary Differential Equations and Dynamical Systems Basic theory of systems of ordinary differential equations; equilibrium solutions, linearization and stability; phase portrait analysis; stable unstable and center manifolds; periodic orbits, homoclinic and heteroclinic orbits; bifurcations and chaos; nonautonomous dynamics; and numerical simulation and nonlinear dynamics. Prerequisites: MATH 252 or consent of the instructor. (3-0-3)

MATH 522 Mathematical Modeling The primary goal of this course is to provide students the power of using the principles and methods of mathematical modeling for studies of complex systems in science and engineering. The students will be introduced to the basic notions of the level of abstractions, and how to work on real problems at different levels. The emphasis throughout is on the synergy between the rigorous mathematical approaches, accurate choice of scientific approximation, engineering estimates, and data analysis. A broad range of physical phenomena, engineering applications as well as biological systems will be considered. The use of methods of applied analysis, theoretical physics, probability and statistics will be described. Prerequisites: MATH 461 and MATH 475 or equivalents. (3-0-3)

MATH 535 Optimization I Introduction to both theoretical and algorithmic aspects of linear optimization; geometry of linear programs, simplex method, anticycling, duality theory and dual simplex method, sensitivity analysis, large scale optimization via Dantzig-Wolfe decomposition and Benders decomposition, interior point methods, network flow problems, integer programming. Prerequisites: Undergraduate course in linear algebra (such as MATH 332). (3-0-3)

MATH 544 Stochastic Dynamics This is an introductory course in mathematical modeling by stochastic differential equations. It is especially appropriate for graduate students who would like to use stochastic methods in their research, or to learn these methods for long term career development. Topics include random variables, mean and variance, Brownian motion, stochastic integration and Ito calculus, stochastic differential equations, random dynamics, numerical simulation, and applications to scientific engineering and financial problems. Prerequisites: MATH 474 or MATH 475 or equivalent. (3-0-3)

MATH 545 Stochastic Partial Differential Equations This course introduces various methods for understanding solutions and dynamical behaviors of stochastic partial differential equations arising from mathematical modeling in science and engineering and other areas. It is designed for graduate students who would like to use stochastic methods in their research or to learn such methods for long term career development. Topics include: Random variables, Brownian motion and stochastic calculus in Hilbert spaces; Stochastic heat equation; Stochastic wave equation; Analytical and approximation techniques; Stochastic numerical simulations via Matlab; Dynamical impact of noises; Stochastic flow and cocycles; Invariant measures, Lyapunov exponents and ergodicity; and applications to engineering and science and other areas. Prerequisites: MATH 543 or MATH 544 or consent of the instructor. (3-0-3)

MATH 553 Discrete Applied Mathematics I Graph theory is the study of systems of points with some of the pairs of points joined by lines. Sample topics include: paths, cycles and trees; adjacency and connectivity; idirected graphs; Hamiltonian and Eulerian graphs and digraphs; intersection grapohs. Applications to the sciences (computer, life, physical, social) and engineering will be introduced throughout the course. This course runs concurrently with MATH 454 but projects and homework are at the graduate level. Prerequisites: MATH 453 or consent of the instructor. (3-0-3)

4.4.11 Relevant Courses in Chemical Engineering

CHE 501 Transport Phenomena Analytical solutions to problems of viscous flow, heat conduction and diffusion. Convective transport processes. Heat and mass transfer with reaction or change of phase. Core course. Prerequisite: CHE 406. (3-0-3)

CHE 503 Chemical Engineering Thermodynamics Laws of thermodynamics applied to chemical engineering problems, properties of real fluids, phase and chemical equilibria, applications to process and auxiliary equipment. Core course. Prerequisites: CHE 351, CHE 451. (3-0-3)

CHE 505 Fluid Properties Prediction and correlation of physical and transport properties using equations of state, thermodynamic relationships, phase and chemical equilibrium. (3-0-3)

CHE 512 Heat Transfer A survey course in conduction, convection and radiation. Problems in condensation and convection are solved with the use of fundamental laws of fluid dynamics. Finite difference and algebraic solutions for unsteady-state and heat-regenerator problems are covered. Prerequisite: CHE 406. (3-0-3)

CHE 518 Mass Transfer Principles of diffusion, both steady and unsteady state, as applied to heat transfer, gas absorption, distillation, drying and extraction. Prerequisite: CHE 406. (3-0-3)

CHE 536 Computational Techniques in Engineering Advanced mathematical techniques, numerical analysis, and solution to problems in transport phenomena, thermodynamics and reaction engineering. Review of iterative solution of algebraic equations. Nonlinear initial and boundary value problems for ordinary differential equations. Formulation and numerical solution of parabolic, elliptic and hyperbolic partial differential equations. Characteristics, formulation and numerical solution of integral equations. Solution of transient two-phase flow problems using CFD codes. Prerequisite: A familiarity with FORTRAN is desirable. Core course for Ph.D. (3-0-3)

CHE 542 Fluidization and Gas-Solids Flow Systems Fluidization phenomena (bubbling, slugging, elutriation and jets in fluidized beds). Multiphase flow approach to fluidization and gas/solids flow systems. Kinetic theory approach to fluid/particle flow systems. Analysis of flow of particles in pneumatic conveying lines (dilute flow) and stand pipe (dense flow). Hydrodynamic analysis of spouted and circulating fluidized beds. Examples from current literature on applications of multiphase flow. Prerequisites: CHE 501, CHE 535. (3-0-3)

CHE 551 Fluid Dynamics Kinematics and dynamics of inviscid flows with applications. Derivation of Navier-Stokes equations. Exact solutions. Boundary layer equations and solutions. Combined inviscid and boundary layer solutions. Introduction to stability, transition and turbulence. Introduction to compressible flow. Prerequisite: CHE 406. (3-0-3)

CHE 580 Biomaterials Metal, ceramic, and polymeric implant materials. Structure-property relationships for biomaterials. Interactions of biomaterials with tissue. Selection and design of materials for medical implants. (3-0-3)

4.4.12 Relevant Courses in Electrical and Computer Engineering

ECE 511 Analysis of Random Signals Probability theory, including discrete and continuous random variables, functions and transformations of random variables. Random processes, including correlation and spectral analysis, the Gaussian process and the response of linear systems to random processes. Prerequisites: ECE 308 and ECE 475 or MATH 475. (3-0-3)

ECE 513 Communication Engineering Fundamentals Review of probability and random processes. AM with noise, FM with noise. Introduction to digital communication. Source coding, signal space analysis, channel modulations, optimum receiver design, channel encoding. Prerequisites: ECE 403 and ECE 475 or MATH 475. (3-0-3)

ECE 531 Linear System Theory Linear spaces and operators, single and multivariable continuous dynamical systems, controllability and observability. Canonical forms, irreducible realizations. Synthesis of compensators and observers. Composite systems, elements of stability. Prerequisite: ECE 308. (3-0-3)

ECE 537 Optimal Feedback Control Principles of feedback design for multivariable systems. Sensitivity functions, principal gains, operator norms and performance specification. Linear quadratic Gaussian (LQG) optimal control, loop transfer recovery (LTR) and design procedures with LQC/LTR methods. H-infinity optimal control, Hankel norm approximation, the 4-block problem, the Youla parameterization and design procedures with H-infinity methods. Prerequisite: ECE 438 and ECE 531. (3-0-3)

ECE 535 Discrete Time Systems Discrete systems. Sampling and reconstruction procedures.Transform techniques of analysis andsynthesis. State space techniques. Discrete controllability,observability and stability.Compensation and digital controllers.Prerequisite: ECE 438. (3-0-3)

ECE 567 Statistical Signal Processing Detection theory and hypothesis testing. Introduction to estimation theory. Properties of estimators, Gauss-Markov theorem. Estimation of random variables: conditional mean estimates, linear minimum mean-square estimation, orthogonality principle, Wiener and Kalman filters. Adaptive filtering. LMS algorithm: properties and applications. Prerequisites: ECE 511, MATH 333. (3-0-3)

ECE 569 Digital Signal Processing II Review of basic DSP theory. Design of digital filters: FIR, IIR, frequency-transformation methods, optimal methods. Discrete Fourier Transform (DFT) and Fast Fourier Transform algorithms. Spectral estimation techniques, classical and parametric techniques. AR, MA, ARMA models. Estimation algorithms. Levinson, Durbin-Levinson and Burg s algorithms. Eigenanalysis algorithms for spectral estimation. Prerequisites: ECE 437 and ECE 475 or MATH 475. (3-0-3)