Department of Mechanical and Energy Engineering

Version 3.2

Effective Spring 2018

Graduate Handbook
for M.S. and Ph.D. students in Mechanical and Energy Engineering

Physical Address
Discovery Park, University of North Texas Suite F101
3940 North Elm, Denton, Texas 76207

Mailing address
1155 Union Circle #311098; Denton, Texas 76203

Phone: 940-565-2400

mee@unt.edu
### Typical Sequence for M.S. Students (Thesis Option)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6 months - 1 year before intended admission date</strong></td>
<td>Apply to Graduate Program (apply directly through <a href="http://www.tgs.unt.edu">www.tgs.unt.edu</a>)</td>
</tr>
<tr>
<td><strong>Week before classes begin</strong></td>
<td>Attend Orientation for new graduate students</td>
</tr>
<tr>
<td><strong>First Year</strong></td>
<td>First semester:</td>
</tr>
<tr>
<td></td>
<td>Work with graduate advisor to select courses for first semester</td>
</tr>
<tr>
<td></td>
<td>Second semester:</td>
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<tr>
<td></td>
<td>By the end of eight weeks</td>
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<tr>
<td></td>
<td>1. Choose Major Professor</td>
</tr>
<tr>
<td></td>
<td>2. Major Professor selects Masters Thesis Committee</td>
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<tr>
<td></td>
<td>3. File Degree Plan</td>
</tr>
<tr>
<td><strong>Second Year</strong></td>
<td>Third semester of degree:</td>
</tr>
<tr>
<td></td>
<td>1. Submit conference paper</td>
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<tr>
<td></td>
<td>2. Submit journal paper</td>
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<td></td>
<td>3. Begin writing thesis</td>
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<tr>
<td></td>
<td>Fourth semester:</td>
</tr>
<tr>
<td></td>
<td>1. Plan possible defense dates and times with advisor and committee members schedule</td>
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<tr>
<td></td>
<td>2. Complete the thesis and submit to thesis committee for review 2 weeks before defense date</td>
</tr>
<tr>
<td></td>
<td>3. Present department seminar</td>
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<tr>
<td></td>
<td>4. Publish abstract and defense announcement 1 week ahead of defense date</td>
</tr>
</tbody>
</table>

Details of sequence and timing will depend on your progress and will be arranged between you and your major professor.
**Typical Sequence for M.S. Students (Non-Thesis Option)**

<table>
<thead>
<tr>
<th>6 months - 1 year before intended admission date</th>
<th>Apply to Graduate Program (apply directly through <a href="http://www.tgs.unt.edu">www.tgs.unt.edu</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week before classes begin</td>
<td>Attend Orientation for new graduate students</td>
</tr>
</tbody>
</table>

**First Year**

- First semester: Work with graduate advisor to select courses for first semester
- Second semester: By the end of eight weeks
  1. Choose professor(s) to do directed study course-work with. The student can list these faculty as their major advisor. Alternatively if a degree plan is chosen with no directed course-work selected, the graduate advisor will function as the major advisor
  2. Work with graduate advisor to complete degree plan
  3. File Degree Plan

**Second Year**

- Third semester of degree:
  1. Continue course-work
- Fourth semester:
  1. File for graduation
  2. Complete coursework
## Typical Sequence for Ph.D. Students

<table>
<thead>
<tr>
<th>Stage</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 months - 1 year before intended admission date</td>
<td>Apply to Graduate Program (apply directly through <a href="http://www.tgs.unt.edu">www.tgs.unt.edu</a>)</td>
</tr>
<tr>
<td>Week before classes begin</td>
<td>Attend Orientation for new graduate students</td>
</tr>
</tbody>
</table>
| First Year                                                          | **First semester:**  
  Take courses relevant to area of focus among Mechanics, Materials Manufacturing, Controls, Thermal, Fluids or Energy  
  By the end of 10 weeks  
  1. Choose Major Professor  
  2. Major Professor selects Doctoral Dissertation Committee  
  3. Begin active research  
  **Second semester:**  
  1. End of six weeks, file Degree Plan  
  2. Plan a poster or conference paper  
  3. Appear for written qualifier examinations in two subjects                                                                                           |
| Second Year                                                         | Continue active research  
  By the end of the first semester following successful completion of both written qualifier exams, present proposal of Ph.D. research to committee  
  Student completing the written qualifier and oral proposal will be qualified for candidacy  
  Outline journal paper and submit for publication                                                                                                     |
| Third Year                                                          | Continue active research  
  Outline journal paper and submit for publication  
  Present department seminar                                                                                                                                                           |
| Fourth Year                                                         | Continue active research  
  Complete dissertation  
  Semester of graduation  
  1. Plan possible defense dates and times with advisor and committee members schedule  
  2. Complete the thesis and submit to committee for review 7 business days before the defense date  
  3. Present department seminar  
  4. Publish abstract and defense announcement 1 week ahead of defense date                                                                                     |

Details of sequence and timing will depend on your progress and will be arranged between you and your major professor.
1. INTRODUCTION

This bulletin provides information about the current practices and policies of the Department of Mechanical and Energy Engineering concerning graduate studies. It is the responsibility of each Graduate Student to familiarize himself or herself with these practices and policies and to ensure that all procedures relating to his or her degree have been fulfilled. Additionally, the student is expected to be thoroughly familiar with general requirements as detailed in this Graduate Bulletin.

The Department of Mechanical and Energy Engineering offers three graduate degrees:

1. M.S. (Master of Science) thesis
2. M.S. (Master of Science) non-thesis
3. Ph.D. (Doctor of Philosophy)

2. ADMISSION PROCEDURES

Applicants are encouraged to concurrently apply to admission through the procedures outlined at Toulouse Graduate School (tgs.unt.edu) and concurrently submit a vita, statement of purpose, recommendation letters and examples of publications to the Graduate Advisor (GA) of Mechanical and Energy Engineering.

The department uses holistic criteria for admissions. The GRE, GPA, publications and research experience are all considered in the admission process. Typical GRE scores should be 155 or higher on the quantitative section and 146 (150 for PhD) or higher in the verbal sections. A high GPA and/or publication record and compatibility with existing research programs in the department are considered valuable. A request for financial support can be part of the cover letter and application of a department TA/RA position can be filled through the website.

3. PLANNING YOUR DEGREE

3.1 Master’s Degree

All students pursuing the master’s degree with a major in mechanical and energy engineering must plan their degree program with the assistance of the graduate advisor, major professor and their advisory committee as applicable. The requirement for graduation is at least 30 semester credit hours for Thesis option or 33 credit hours for Non-thesis option. The student needs to maintain at least a B average in all graduate courses.

Additional requirements to earn M.S. degree are as follow:

1. All M.S. Students (for both thesis and non-thesis options) must select one of the five MEE concentrated tracks (Materials and Manufacturing, Mechanical Systems and Design, Modeling and Simulation, Thermal-Fluid Systems, and Energy). A total of 21 credits (seven courses) must come from the required core and elective courses as prescribed in Appendix C.
2. Each MS student must take at least 21 credits in MEE, including the core and elective courses within the track and outside.
3. All M.S. students must register and attend MEE seminars for one semester.

Option 1: Thesis (30 Credits)

The graduate credit requirement for the Thesis option MS degree is 30 semester credit hours chosen as follows:

1. Twelve semester credit hours of coursework from core and one area of specialization in General Energy, Thermal Energy and Fluids or Mechanics and Controls listed in the Department of Mechanical and Energy Engineering website and graduate handbook.
2. Twelve semester credit hours of coursework chosen from 5000 or higher courses offered by the Department of Mechanical and Energy Engineering and related departments.\(^1\) The selection of courses

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\(^1\) Some Mechanical and Energy Engineering relevant courses are taught in Engineering Technology, Materials Science and Engineering and Electrical Engineering. The confirmation that a course will be considered valid for an MEE
should be done with the approval of the student's thesis advisor and MEEN graduate advisor.

3. A maximum of 3 credit hours of directed study or research is allowed as part of the 24 hours of coursework.

4. Six semester credit hours of MEEN 5950 - Master's Thesis. Work for the master's thesis is comprised of an independent and original study. As part of these requirements, the student must present and defend a written thesis that must be approved by the major professor and the advisory committee and filed with the graduate dean’s office. The thesis must conform to the graduate school requirements, which may be found at graduateschool.unt.edu. It is expected that this material will be of archival quality.

5. An oral presentation of the master's thesis is required. A decision on acceptance of the thesis will be made by the student’s advisory committee. For the thesis format, additional preparation guidelines can be found on the website of the graduate school.

**Option 2: Non-thesis (33 Credits)**

The graduate credit requirement for the Non-thesis option MS degree is 33 semester credit hours chosen as follows:

1. Twenty seven credits of coursework chosen from graduate level courses offered by the Department of Mechanical and Energy Engineering and related departments approved by the graduate advisor.

2. Out of 33 credits, six credit hours can be taken as Directed Study (MEEN 5890).

3. Students taking Directed study courses must submit a report.

**3.2 Ph.D.**

All students pursuing the doctoral degree with a major in mechanical and energy engineering must plan their degree program with the assistance of their major professor and their advisory committee. The requirement for graduation is at least 72 semester credit hours beyond the bachelors or 42 hours beyond the MS Thesis. The student needs to maintain at least a B average in all graduate courses.

The graduate credit requirement for a student with a BS degree requiring 72 hours is as follows:

1. Twelve semester credit hours of core courses chosen from the listing provided by the Department of Mechanical and Energy Engineering.

2. A minimum of nine semester credit hours of electives that are selected from one of the three areas: General Energy, Thermal Energy & Fluids or Solid Mechanics & Controls. Courses are selected with approval of the student's dissertation advisor and graduate advisor.

3. A minimum of fifteen semester credit hours of courses from Mechanical and Energy Engineering and related fields approved by the dissertation advisor.

4. Three hours of seminar.

5. A minimum of twelve hours of dissertation hours that can be registered for only on successful completion of the Ph.D. qualifying exam.

The graduate credit requirements for a student with a MS degree requiring 42 hours is as follows:

1. Twelve semester hours of core courses chosen from the core course listing provided by the Department of Mechanical and Energy Engineering and posted on the website.

2. A minimum of nine credit hours of electives that are selected from one of three areas: General Energy, Thermal Energy and Fluids or Solid Mechanics and Controls. Courses are selected with the approval of the student’s dissertation advisor and graduate advisor.

3. A minimum of three credit hours of course offered at the 5000 level or higher offered by Mechanical and Energy Engineering and related fields.

4. Up to six hours of research credit hours.

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degree will be provided by the Graduate Advisor. Students should confirm this prior to taking such courses if not on their degree plan.

2 Some Mechanical and Energy Engineering relevant courses are taught in Engineering Technology, Materials Science and Engineering and Electrical Engineering. The confirmation that a course will be considered valid for an MEE degree will be provided by the Graduate Advisor. Students should confirm this prior to taking such courses if not on their degree plan.
4. Three hours of seminar
5. A minimum of nine hours of dissertation credits (6950) that can be registered for only on being admitted to candidacy.

Examinations
1. Within two years of being admitted in the doctoral program, the student should do two written qualifying examinations in the areas of specialization in the following areas: General Energy, Thermal Energy and Fluids or Solid Mechanics and Controls. These are covered by selecting two topics among the 6 offered: Mechanics, Materials Manufacturing, Controls, Energy, Thermal and Fluids. A passing grade corresponds to achieving a 90 or above in the written exam. Students obtaining between 70 and 89 will be offered a supplementary oral exam before the committee corresponding to the area being tested. The committee will weigh the written and oral exam to determine whether the student has successfully qualified.
2. After passing the written qualifying exam, students are required to complete and defend an original research proposal in the form of an oral exam that, if executed, would lead to a PhD dissertation. The proposal oral exam should be evaluated by the major advisor and dissertation committee members.
3. On passing the written qualifier and oral research proposal examination by the examination committee, the applicant is admitted to candidacy.
4. A pre-dissertation presentation must be conducted between 6 and 12 months prior to final dissertation defense. This presentation is open to the PhD committee members and the general public. This presentation should be announced to all graduate students and faculty with a minimum two-week notice via bulletin board, email and website. It is desired that all graduate students and faculty be invited to attend as a part of seminar series. Committee members will identify weaknesses and shortcomings in the research, and will make specific, actionable recommendations to strengthen the dissertation.
5. The students must give a final oral dissertation presentation to the dissertation committee and open to the public. The dissertation must be submitted to the committee at least seven days before the oral defense and dissemination of the time and place of the presentation made available to the MEE faculty and students. The students will revise the dissertation following the suggestions of the thesis committee and submit the final dissertation to the graduate school of UNT.

4. SELECTION OF A MAJOR PROFESSOR AND ADVISORY COMMITTEE:

Usually by the end of the initial semester in graduate school, and certainly by no later than the end of the first year, the student will be expected to determine his or her specialization and choose a major professor. The selection of a major professor for a M.S. or Ph.D. student should be done only after having interviewed all of the research faculty in the student's major area of interest. When the selection has been made, the direct supervision of the student's program and progress toward the degree sought will be transferred to his major professor.

After consultation with the student, the major professor will propose an advisory committee to the GA for approval; the GA will then submit the committee names to the Graduate Dean for approval. It is imperative that this committee be selected and approved as soon as possible after selecting a major professor because the committee (which includes the major professor as chair) determines the course curriculum for the student.

The minimum committee requirements for a M.S. Degree must be at least three members (including the major professor). The committee should comprise a majority of Mechanical and Energy Engineering faculty having an appointment greater than 50% in the MEE department. External committee members having industrial or application expertise in the area of research are encouraged. A graduate associate faculty status for the duration of the student’s degree can be filed by providing a vita of the external member to the MEE graduate advisor.

The minimum requirements for a Ph.D. Advisory committee must be at least four members (including the major professor). The committee should comprise a majority of Mechanical and Energy Engineering faculty having an appointment greater than 50% in the MEE department. External committee members having industrial or application expertise in the area of research are encouraged. A graduate associate
faculty status for the duration of the student’s degree can be filed by providing a vita of the external member and a description of how the external committee member enhances the evaluation of the dissertation to the MEE graduate advisor.

By the middle of the second semester, a degree plan will be drawn up for the student. The GA will ensure that all graduate requirements are being met. Although the major responsibility resides with the major professor and the advisory committee in academic decisions concerning the student's status in graduate school, the GA will monitor the student's progress to ensure minimal standards are being met.

5. Function of the Ph.D. Advisory Committee

The UNT members of the Advisory Committee will officially meet with the student at least once each year, beginning with the second year, until the student graduates. The external committee member may also be invited to participate. The committee members and student will discuss his/her academic (research and coursework) progress to date and the committee will issue a formal, written assessment of this progress. This written assessment will be via a form obtained from and provided to the Student Services Office and will be placed in the student’s permanent file.

During the student’s third year, the meeting with the committee will be preceded by a formal department-wide seminar in which a topic related to student’s research is presented to all of the graduate students, to the committee and to other faculty in the department. The talk should be scheduled in consultation with the faculty organizing the department seminar. Following the seminar, the committee will meet privately with the student to assess his/her overall progress.

6. Records

It is the responsibility of the student, together with the major professor, to report all additions and changes to a student’s record to the Student Services Office to ensure that the student’s record is current. These reports should include:

a. Choice of a major professor
b. Formation of the Advisory Committee
c. Filing of a degree plan
d. Results of the yearly assessments of the student’s progress by the Advisory Committee
e. Qualifier results of the core area of MEE
f. Results of the final oral examination and the date of the student’s departure

Grades need not be reported since they are directly available to the Student Services Office.

7. Research and Final Comprehensive Examination

A comprehensive examination is required by the University for all graduate students at the completion of their graduate studies. This examination is administered by the student's committee and the results are reported to the Dean of the Toulouse Graduate School. Each student should check the University calendar to meet required deadlines.

Ph.D. dissertations and Master's theses must be of scientific significance and suitable for publication in refereed scientific journals. A final oral examination is required which will be primarily a defense of the thesis or dissertation. For a Ph.D. candidate, it is required that at least two papers will have been accepted by a refereed journal by the time of the oral defense on a topic related to his/her dissertation. A copy of the manuscript published or under consideration should be submitted with the dissertation to his/her dissertation committee.

8. Other General Policies
8.1 Seminar Program:

The seminar program is a valuable part of a student's training, as it gives direct exposure to research areas outside the student's immediate interest. Students enrolled in the Ph.D. program should attend seminar to be informed about contemporary context to their research. Attendance at Departmental Seminars (defined as those given by UNT faculty and visiting speakers and student seminars) is compulsory unless the student has a conflict with a class or teaching assignment, in which case the Seminar Chair should be informed in advance.

Three seminar hours are considered part of their PhD degree plan and during semesters when they are enrolled, they should follow additional requirements outlined by the seminar coordinator.

All Ph.D. students will give a departmental wide seminar during his/her third year. The seminar should be on a topic related to student’s research is presented to all of the graduate students, his/her committee and to other faculty in the department. This talk will be part of the department’s MEEN 5940 seminar program and should be coordinated with the Seminar Chair.

8.2 Student Load and Graduate Requirements:

All full-time graduate students are required to take a full load, as determined by the Department. Students receiving departmental or grant support must be full-time students.

An average of "B" must be maintained in all formal graduate courses taken by graduate students. Special Problems, Seminar, Thesis, or Dissertation courses are not included in computing the grade point average. Graduate School policy states that a student who does not maintain a "B" average (as defined above) may be suspended. Such a decision is made by the Toulouse Graduate School, after consultation with the Mechanical and Energy Engineering Department.

8.3 Financial Assistance

Financial support for graduate students is provided in a number of ways in the Mechanical and Energy Engineering Department which include: teaching or laboratory assistantships, preppers, graders, (b) research fellowships made available through research grants to individual faculty members, (c) individual student scholarships or awards available to qualified students from a variety of agencies both public and private, and (d) a number of fellowships and scholarships are often awarded through the College of Engineering, Toulouse Graduate School and the Department of Mechanical and Energy Engineering.

As full-time students in the department, TAs, graders, employees not only fulfill their work obligations, but work on their courses and research. All of these combined are considered to be a full-time activity. Therefore, students employed through department financial assistance, are not permitted to have other simultaneous outside employment unless prior approval has been obtained from the Department.
Master’s Degree Thesis Defense Announcement

Friday, March 13, 11:00AM at MEE Conference room

Continuum Model for Effective Properties of Orthotropic Truss Lattice Materials

Adithya Challapalli3 (Thesis advisor: Dr. Jaehyung Ju)

Abstract: Cellular materials, often called lattice materials, are increasingly receiving attention for their ultralight structures with high specific strength, excellent impact absorption, acoustic insulation, heat dissipation media and compact heat exchangers. In alignment with emerging additive manufacturing (AM) technology, realization of the structural applications of the lattice materials appears to be becoming faster. Considering the direction dependent material properties of the products with AM, by directionally dependent printing resolution, effective moduli of lattice structures appear to be directionally dependent. In this paper, we develop a constitutive model of a lattice structure, which is an octet-truss with a base material having an orthotropic material property considering AM. One case study is conducted with an orthotropic property of a base material in 3D Printing. A polyjet based 3D printing material having an orthotropic property with a 9% difference in the principal direction provides difference in the axial and shear moduli in the octet-truss by 2.3 and 4.6%. Experimental validation of the effective properties of octet-truss is done for uniaxial compression test are conducted with a 3D printed octet-truss with a photo-polymer (Procast, 3D Systems). The theoretical values based on the micro-buckling of truss member are used to estimate the failure strength well. Modulus value appears a little overestimate compared with the experiment. Finite element (FE) simulations on uniaxial loading (both compression and tension) of octet-truss lattice materials are conducted. New effective properties and strengths for the octet-truss lattice structure were developed considering the observed behavior of the octet-truss structure under macroscopic compression and tension.


A. Challapalli, SAMPE National Student Additive Manufacturing Contest, Seattle, WA, 06/2014, 2nd Place ($500) online
Students are to pass exams in two of the topics listed below. For students entering the PhD program Fall 2017 and forward they will have 2 years to successfully pass the qualifying exam and be admitted to Ph.D. candidacy. Students admitted prior to Fall 2017 and transferring from the MTSE-MEE program will be afforded some flexibility as determined on an individual basis by the MEE graduate committee.

<table>
<thead>
<tr>
<th>Qualifier Topic</th>
<th>Faculty lead</th>
<th>Team contributing faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Solid Mechanics</td>
<td>Nandika D’Souza</td>
<td>Sheldon Shi, Haifeng Zhang</td>
</tr>
<tr>
<td>b. Materials and</td>
<td>Sheldon Shi</td>
<td>Nandika D’Souza, Mark</td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td>Wasikowski</td>
</tr>
<tr>
<td>c. Thermal</td>
<td>Tae-Youl Choi</td>
<td>Richard Zhang, Vish Prasad</td>
</tr>
<tr>
<td>d. Fluids</td>
<td>Hamid Sadat hosseini</td>
<td>Tae-Youl Choi, Weihuan Zhao</td>
</tr>
<tr>
<td>e. Vibrations and</td>
<td>Haifeng Zhang</td>
<td>Cherish Qualls</td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Energy</td>
<td>Russel Reid</td>
<td>K. John, X. Li</td>
</tr>
</tbody>
</table>

Students can review the reading list and meet with the lead faculty to get additional advice on valuable reading material or courses they could do prior to doing the qualifier.

1. **Solid Mechanics**
   Committee: N. D’Souza, Sheldon Shi, Haifeng Zhang
   Courses relevant to the exam: ENGR 2332; MEEN5410
   Textbooks which can be used for the qualifying exam:

   Topics which can be covered for the qualifying exam (Solid Mechanics):
   - Elementary Mechanics of Materials (Axial Loading, Bending, Torsion, Column Buckling, Plastic Deformation)
   - Stress, Strain, Constitutive Relations, Stress decomposition (volumetric and distortional)
   - Failure Criteria including Fracture and Fatigue
   - Energy Methods
   - Theory of Elasticity

2. **Materials and Manufacturing**
   Committee: Sheldon Shi, N. D’Souza, M. Wasikowski
   Courses relevant to the area: MEEN 3100, MEEN 5800.002 (Bioproducts)

   Topics to be covered:
   - Dimensional characteristics, inspection, and product Quality Assurance
   - Metal Casting
   - Bulk Deformation
   - Sheet Metal Forming
   - Materials Removal Processes
   - Polymer Processing
   - Powders Processing
   - Joining Processes
   - Microelectronics Processing
3. Thermal/Heat Transfer
Committees: T.-Y. Choi, R. Zhang, V. Prasad
Courses relevant: MEEN2210 and MEEN 3210
by Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner and Margaret B. Bailey.
Topics to be covered:
Energy and the first law of thermodynamics
Evaluating properties
Control volume analysis
The second law of thermodynamics; using entropy

Topics to be covered:
Steady state conduction (One and two-dimensional)
Transient conduction
Forced convection: internal / external flow
Free (Natural) Convection

4. Fluid Mechanics
Committee: H. Sadat Hosseini, T. Y. Choi, W. Zhao
Courses relevant: MEEN 3120
Topics to be covered:
Governing equations
Control volume analysis
Dimensional analysis
2-D potential flows
Exact solutions of viscous flows of incompressible flows
Boundary layer analysis
Buoyancy-driven flows

5. Vibrations/Controls:
Committee: H. Zhang, C. Qualls
Courses relevant: MEEN3230, MEEN4160 and MEEN 5600
Reference textbook:
Topics to be covered:
Modeling of mechanical, electrical, fluid, thermal and mixed energy domain systems (in state-variable or input-output form).
Derivation and analysis of system response in time domain. Solution of system response using the Laplace transform method. The effect of system parameters on system response and stability.
Mechanical vibration: free vibration, harmonic excitation, general force excitation.
Vibration suppression.
Feedback control system for a linear time-invariant system. PID (proportional - integral - derivative) control. Lead-lag and lag-lead control.
Design of a control system using frequency response. Gain margin, phase margin and bandwidth.
6. Energy:
Committee: R. Reid, X. Li

Courses relevant: MEEN 5110 Alternative energy

References:

Topics to be covered:
Basic concepts: Energy production to consumption; Sustainability index
Efficiencies: Thermodynamic limits; Heat transport; Conversions
Fossil fuels, energy, and economics: Fuel types, production, environmental and economic impacts
Solar Energy: System types, performance criteria, and potentials
Wind Energy: Resources, conversion principle, measures of sustainability
Commercial and Residential Buildings: Energy efficiency strategies; Building materials; heat transfer in building design
Energy storage: mechanical and thermal energy storage, batteries, super capacitors, and fuel cells.

Open subject: Technical, environmental and economic challenges of one of the energy forms other than those listed above (e.g., transportation, ocean, geothermal, hydropower, etc.)
APPENDIX C – Required and Elective Courses

MEEN List of Graduate Courses in each Concentration

1. Materials and Manufacturing (Material Reliability and Manufacturing)
   - **Required core courses**
     MEEN 5410 - Advance Solid Mechanics
     MEEN 5520 - Advanced Manufacturing (or Bioproducts or Automotive Manufacturing)
     MEEN 5800 – Topics in Mechanical and Energy Engineering: Experimental Design
     MTSE 5100 - Fundamental Concepts of Materials Science or MEEN 5440 Finite Element Analysis
   - **Electives**
     MEEN 5440 - Finite Element Analysis
     MEEN 5152 - Mechanics of Composites and Foams for Lightweight Structures
     MEEN 5420 - Continuum Mechanics
     MTSE 5020 - Mechanical Properties of Materials
     MTSE 5400 - Advanced Polymer Physics and Chemistry
     MTSE 5550 - Materials and Mechanics for MEMS Devices
     MTSE 5710 - Computational Materials Science
     MTSE 6110 - Applied Fracture Mechanics

2. Mechanical Systems and Design
   - **Required core courses**
     MEEN 5140 - Advanced Mathematical Methods for Engineers
     MEEN 5410 - Advanced Solid Mechanics
     MEEN 5600 - Feedback Control of Dynamic Systems
     MEEN 5640 - Applied Engineering Vibrations* (Cross listed as MFET 5140)
   - **Electives**
     MEEN 5440 - Finite Element Analysis
     MEEN 5800 - Topics in Mechanical and Energy Engineering: Experimental Design
     MEEN 5152 - Mechanics of Composites and Foams for Lightweight Structures
     MEEN 5610 - Sensors & Actuators
     MEEN 5800 - Topics in Mechanical and Energy Engineering: Geothermal Heat Pumps
     MEEN 6200 - Theory of Elasticity
     MTSE 6110 - Applied Fracture Mechanics

3. Modeling and Simulation
   - **Required core courses**
     MEEN 5140 - Advanced Mathematical Methods for Engineers
     MEEN 5440 - Finite Element Analysis
   - **Electives**
     MEEN 6000 - Advanced Numerical Methods
     MEEN 5311 - Convective Heat Transfer II*
     MEEN 5340 - Advanced Fluid Mechanics*
     MEEN 5420 - Continuum Mechanics**
     MEEN 5220 - Computational Fluid Dynamics and Heat Transfer*
     MEEN 5315 - Nanoscale Energy Transport
     CSCE 5160 - Parallel Processing and Algorithms
     CSCE 5230 - Methods of Numerical Computation
     CSCE 5420 - Software Development
     CSCE 5810 - Biocomputing
     MTSE 5710 - Computational Materials Science**

*Note:
The every student under the Modeling and Simulation track will pick from electives a group of courses either in the area of mechanics (**) or in the area of thermal-fluid sciences (*), or both.
4. Thermal-Fluid Systems

- Required core courses
  MEEN 5140 - Advanced Mathematical Methods for Engineers
  MEEN 5300 - Advanced Thermodynamics
  MEEN 5311 - Convective Heat Transfer II
  MEEN 5340 - Advanced Fluid Mechanics

- Electives
  MEEN 5000 - Energy: The Fundamentals
  MEEN 5110 - Alternative Energy
  MEEN 5200 - Principles of HVAC
  MEEN 5220 - Computational Fluid Dynamics and Heat Transfer
  MEEN 5310 - Conduction and Radiation Heat Transfer
  MEEN 5315 - Nanoscale Energy Transport
  MEEN 5330 - Combustion Science and Engineering
  MEEN 5800 - Topics in Mechanical and Energy Engineering: Geothermal Heat Pumps

5. Energy

- Required core courses
  MEEN 5000 - Energy: The Fundamentals
  MEEN 5110 - Alternative Energy
  MEEN 5210 - Solar Energy

- Electives
  MEEN 5140 - Advanced Mathematical Methods for Engineers
  MEEN 5112 - Nuclear Energy (not listed as a graduate course)
  MEEN 5150 - Thermal Energy Storage Systems and Applications
  MEEN 5200 - Principles of HVAC
  MEEN 5240 - Energy: A World Perspective
  MEEN 5310 - Conduction and Radiation Heat Transfer
  MEEN 5330 - Combustion Science and Engineering
  MEEN 5332 - Air Pollution Control Engineering
  MEEN 5800 - Topics in Mechanical and Energy Engineering: Geothermal Heat Pumps
  BIOL 6341 - Advanced Environmental Impact Assessment
  EENG 5940 - Renewable Electrical Power Systems