Department of Mechanical and Energy Engineering

Version 3.2

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

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Typical Sequence for M.S. Students (Thesis Option)

6 months - 1 year before intended admission date	Apply to Graduate Program (apply directly through www.tgs.unt.edu)
Week before classes begin	Attend Orientation for new graduate students
First Year	First semester: Work with graduate advisor to select courses based on concentration for first semester Second semester: By the end of eight weeks 1. Choose Major Professor 2. Major Professor selects Masters Thesis Committee 3. File Degree Plan
Second Year	Third semester of degree: 1. Submit conference paper 2. Submit journal paper 3. Begin writing thesis Fourth semester: 1. File for graduation 2. Plan possible defense dates and times with advisor and committee members schedule 3. Complete the thesis and submit to thesis committee for review 2 weeks before defense date 4. Present department seminar 5. 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.

Typical Sequence for M.S. Students (Non-Thesis Option)

6 months - 1 year before intended admission date	Apply to Graduate Program (apply directly through www.tgs.unt.edu)
Week before classes begin	Attend Orientation for new graduate students
First Year	First semester: Work with graduate advisor to select courses based on concentration 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

6 months - 1 year before intended admission date	Apply to Graduate Program (apply directly through www.tgs.unt.edu)
Week before classes begin	Attend Orientation for new graduate students
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. File for graduation 2. Plan possible defense dates and times with advisor and committee members schedule 3. Complete the thesis and submit to committee for review 7 business days before the defense date 4. Present department seminar 5. 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 four graduate degrees:

1. Mechanical and Energy Engineering with a concentration in Energy Systems, MS
2. Mechanical and Energy Engineering, MS
3. Mechanical and Energy Engineering with a concentration in Biomedical Engineering, PhD
4. Mechanical and Energy Engineering, PhD

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, Materials and Manufacturing, or Mechanics and Controls listed in the Department of Mechanical and Energy Engineering website and graduate handbook.
2. Twelve semester credit hours of course work chosen from 5000 or higher courses offered by the Department of Mechanical and Energy Engineering and related departments. [1] The selection of courses

[1] Some Mechanical and Energy Engineering relevant courses are taught in Engineering Technology, Materials Science

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 www.tgs.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[2] 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.

Students entering the PhD with a major in mechanical and energy engineering with a bachelor of science must complete 72 semester hours at the graduate level as follows:

1. Twelve semester credit hours of core courses chosen from the listing of concentrations provided by the Department of Mechanical and Energy Engineering (see Appendix C).
2. A minimum of 9 semester credit hours of electives are selected from one of the three areas: general energy, thermal energy and fluids, or solid mechanics and controls. Courses are selected with approval of the student's dissertation advisor and graduate advisor.
3. A minimum of 15 semester credit hours of courses from mechanical and energy engineering and related fields approved by the dissertation advisor.
4. Up to 21 hours of research credits.
5. Up to 3 hours of seminar.
6. A minimum of 12 hours of dissertation (MEEN 6950) credit hours that can be registered for only upon the successful completion of the PhD qualifying examination (both written and oral qualifying exams).

Students entering the PhD with a major in mechanical and energy engineering with a master of science must complete 42 semester credit hours of course work as follows:

1. Twelve semester hours of core courses chosen from the core course listing of concentrations provided by the Department of Mechanical and Energy Engineering and posted on its web site (see Appendix C).

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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.

[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.

2. A minimum of 9 semester credit hours of electives that are selected form one of four areas: general energy, thermal energy and fluids, materials and manufacturing, or solid mechanics and controls. Courses are selected with the approval of the student's dissertation advisor and graduate advisor.
3. A minimum of 3 credit hours of courses at the 5000 level or higher offered by mechanical and energy engineering and related fields.
4. Up to 6 hours of research credit hours.
5. Up to 3 hours of seminar.
6. A minimum of 9 hours of dissertation (MEEN 6950) credit hours that can be registered for only upon the successful completion of the PhD qualifying examination (both written and oral qualifying exams).

Examinations
1. Within one year 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. Students must pass the oral qualifying exam within two semesters after passing the written qualifying exam.
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 five 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 (one seminar hour for MS) 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: (a) 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.

Awarding of the TAs and graders depends on students' qualification and is recommended in each semester by the graduate committee per UNT policy 06.021. Students' academic and research performance as well as TA performance will be evaluated in each semester and only qualified students will renew their positions. Continuation of funding for TA is subject to passing qualifying exams, good TA performance, and good

academic standing.

APPENDIX A- Sample Thesis or Dissertation Oral Defense Announcement: to be posted 7 days before defense.

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 Challapalli[3] (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.

[3] **A.Challapalli** and J. Ju, 2014, Continuum Model for Effective Properties of Orthotropic Octet-Truss Lattice Materials, In *Proceedings of the ASME International Mechanical Engineering Congress and Exposition*, IMECE2014-38925, Montreal, Canada.

A. Challapalli, SAMPE National Student Additive Manufacturing Contest, Seattle, WA, 06/2014, **2nd Place** ($500) online

APPENDIX B – Qualifier guidelines (2015-2016 academic year)

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.

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

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:
Arthur P. Boresi and Richard J. Schmidt, Advanced Mechanics of Materials, 6th Edition (currently used for MEEN 5410 "Advanced Solid Mechanics")

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)
Fundamentals of Modern Manufacturing by Groover 6th Edition. ISBN 9781118231463

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
Textbook 1 (Thermodynamics): *Fundamentals of Engineering Thermodynamics*, 7th Edition, ISBN-13: 978-0470495902
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

Textbook 2 (Heat Transfer): *Fundamentals of Heat and Mass Transfer*, 6th Edition, ISBN-13: 978-0471457275, by Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, Adrienne S. Lavine

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
Textbook: Fundamentals of Fluid Mechanics by Munson et al., ISBN 978-0-470-26284-9; Fluid Mechanics by F. White, ISBN 0077422414

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:
William J. Palm III, Modeling, Analysis, and Control of Dynamic Systems, 2nd Ed., John Wiley & Sons, Inc.
D. Inman, "Engineering Vibration," 3rd Ed. Prentice Hall.
Rao, “Mechanical Vibrations”, Fifth edition, Prentice Hall

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.
Transfer function. Frequency response analysis of a system. Bode plots.
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

Textbook: Principles of Sustainable Energy Systems by Frank Kreith and Susan Krumdieck, ISB#13:978-1-4665-5696-6, 2014, CRC Press (Taylor & Francis).

Courses relevant: MEEN 5110 Alternative energy

References:

B. K. Hodge, "Alternative Energy Systems and Applications,"

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.)

MEEN List of Graduate Courses in each Concentration

1. **Materials and Manufacturing (Material Reliability and Manufacturing)**

- *Required core courses*
MEEN 5410 - Advanced 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
MEEN 5220 - Computational Fluid Dynamics and Heat Transfer*
MEEN 6000 - Advanced Numerical Methods (or MTSE 5710 or CSCE 5230)

- *Electives*
MEEN 5311 - Convective Heat Transfer II*
MEEN 5340 - Advanced Fluid Mechanics*
MEEN 5420 - Continuum Mechanics**
MEEN 5410 - Advance Solid Mechanics
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:
Every student under the Modeling and Simulation track will pick from electives a group of courses either in the area of machanics (**) 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 5800 - Energy Harvesting
MEEN 5140 - Advanced Mathematical Methods for Engineers

- *Electives*
MEEN 5112 - Nuclear Energy
MEEN 5150 - Thermal Energy Storage Systems and Applications
MEEN 5200 - Principles of HVAC
MEEN 5311 - Convective Heat Transfer II

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
MEEN 5210 - Solar Energy
BIOL 6341 - Advanced Environmental Impact Assessment
EENG 5940 - Renewable Electrical Power Systems