Graduate Programs
Mechanical Engineering
(Ph.D., M.S. and M. Eng.)

Department of Mechanical Engineering

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Introduction

Graduate Programs in Mechanical Engineering (ME)

The new ME graduate programs continue to include a Ph.D. program and an M.S. program in ME. The M.S. program allows the student to focus on one of the following concentrations: i) Thermo-fluid Sciences; ii) Engineering Mechanics; and iii) Materials and Manufacturing, and iv) Renewable Energy. The courses offered under each concentration have been revised based on the current international trends and several courses have been introduced that address strategic needs of the Kingdom of Saudi Arabia including water desalination, renewable energy, clean combustion, carbon capture, and energy efficiency.

Master of Engineering (M. Eng.) Program

To align its activities with the latest industrial demands and trends, the ME department is offering a new course-based Master of Engineering (M. Eng.) program in Mechanical Engineering with four concentrations: i) Thermo-fluid Sciences, ii) Engineering Mechanics, iii) Materials and Manufacturing, and iv) Renewable Energy. The program is tailored for individuals who require a more career-oriented advancement of knowledge rather than the more research-oriented M.S. program. The motivation for establishing these program options is primarily to enable engineers working in the industry or in governmental agencies to pursue graduate studies in areas of direct relevance to their profession for the purpose of improving their engineering background and technical skills and who are not interested to pursue doctoral degrees. The M. Eng. program structure has been designed based on the requirements of the Deanship of Graduate Studies at KFUPM as well as benchmarking with top universities in the USA. The program was further improved based on the input received from ME faculty, alumni, and various departments at KFUPM.

The introduction of the Renewable Energy option is in response to the new initiative of the Kingdom to develop a renewable energy industry as a key objective in Vision 2030 aiming to diversify the country's economy away from heavily reliance on oil and gas and to reach environmental sustainability. Saudi Arabia has substantial potential in solar and wind energy production as it is ranked the 6th and 13th country worldwide, respectively. The national plan is to supply 9,500 MW, or 10% of the country's power demand, from renewable sources in the short term (by 2023). In the long-term (by 2032), the country aims to generate as much as one third of its power demands using renewable energy. Therefore, the ME department is offering a new concentration under M.S. and M. Eng. programs in Renewable Energy to contribute to the human capacity development required to realize these initiatives. Table 1 summarizes the three programs in ME and the options offered under the M.S. and M. Eng. programs.

Table 1: Summary of Graduate Programs in Mechanical Engineering Department at KFUPM.

Program	**Master of Science (M.S.) Program**	**Master of Engineering (M. Eng.) Program**	**Ph.D. Program**
Options	1. Thermofluid Sciences	1. Thermofluid Sciences	Ph.D. in ME
	2. Engineering Mechanics	2. Engineering Mechanics	
	3. Materials & Manufacturing	3. Materials & Manufacturing	
	4. Renewable Energy	4. Renewable Energy	

Teaching & Research Facilities

The Mechanical Engineering Department is home for more than 55 Ph.D. holder faculty members with diverse background in almost all mechanical engineering subfields. The Mechanical Engineering Department has several laboratories equipped with teaching and research facilities including: Design, Rapid Prototyping, Air-conditioning and Refrigeration, Fluid Mechanics, Pumping Machinery, Heat Transfer, Heat Engines, Laser, Dynamics, Materials Science, Corrosion, Nanotechnology, Membrane, Polymer Processing, Stress Analysis, Metrology, Tribology, Desalination, and Mechatronics. The Department also has a central modern machine shop to support teaching and research activities.

Programs Educational Objectives (PEO)

M.S. Program

Graduates of the M.S. program in Mechanical Engineering at KFUPM are expected to demonstrate the following capabilities after few years of graduation:

1. To apply their **knowledge-based approaches** to address technical and societal problems and use advanced analysis and modern engineering tools to develop their solutions.
2. To apply their **research skills** in formulating problems and providing innovative and sustainable solutions to emerging local and global challenges to industry and society.
3. To demonstrate **professional competence** needed to accelerate their career development, commit to ethical conduct, engage in lifelong learning, and seek out positions of leadership within their profession and their community.

M. Eng. Program

Graduates of the M. Eng. program in Mechanical Engineering at KFUPM are expected to demonstrate the following capabilities after few years of graduation:

1. To apply their **knowledge-based approaches** to address technical and societal problems and use advanced analysis and modern engineering tools to develop their solutions.
2. To apply their **analytical skills, engineering practices, and industrial experiences** to identify, formulate and solve problems in their professional practice.
3. To demonstrate **professional competence** needed to accelerate their career development, commit to ethical conduct, engage in lifelong learning, and seek out positions of leadership within their profession and their community.

Ph.D. Program

Graduates of the Ph.D. program in Mechanical Engineering at KFUPM are expected to demonstrate the following capabilities after few years of graduation:

1. To apply **critical and independent thinking** in formulating problems and providing innovative and sustainable solutions that constitute original contribution to engineering knowledge.
2. To conduct **impactful research** addressing local and global challenges to industry and society.
3. To demonstrate **professional competence** needed to accelerate their career development, commit to ethical conduct, engage in lifelong learning, and seek out positions of leadership within their profession and their community.

Student Learning Outcomes (SLO)

M.S. Program

Upon completing the requirements of the M.S. program in Mechanical Engineering at KFUPM, graduates will:

A. Demonstrate advanced knowledge in the selected area of study.
B. Use modern engineering tools commonly used in research and engineering analysis in the selected area of study.
C. Have the ability to formulate and execute a research plan, generate and analyze research results, and communicate the findings through technical papers and seminar presentations in full adherence to high standard of research ethics.
D. Demonstrate best practices in professional development including lifelong learning, collaborative work, safety, environment, and social and ethical responsibilities.
E. Demonstrate proper qualifications for hiring in industry, research institutions, or pursuing higher degrees.

M. Eng. Program

Upon completing the requirements of the M. Eng. program in Mechanical Engineering at KFUPM, graduates will:

A. Demonstrate advanced knowledge in the selected area of study.
B. Use modern engineering tools commonly used in engineering analysis in the selected area of study.
C. Demonstrate best practices in professional development including lifelong learning, collaborative work, safety, environment, technical writing, and seminar presentations.
D. Recognize and follow professional practices and understand the social and ethical responsibilities.

Ph.D. program

Upon completing the requirements of the Ph.D. program in Mechanical Engineering at KFUPM, graduates will:

A. Demonstrate a command of knowledge in a core subject area of mechanical engineering and in a minor area consistent with their degree plans.
B. Use advanced tools and apply technical skills to conduct independent research on an original topic using interdisciplinary approach.
C. Effectively communicate scientific outcomes through publications in scholarly publications and seminar presentations in full adherence to high standard of research ethics.
D. Demonstrate best practices in professional development including lifelong learning, collaborative work, safety, environment, and social and ethical responsibilities.
E. Demonstrate proper qualifications and readiness for hiring in research institutions, academia, or industry.

Admission Requirements

M.S. Program

The minimum requirements for admission to the Master of Science program in the College of Graduate Studies as a regular graduate student with full standing in Mechanical Engineering are:

- A Bachelor's Degree in Mechanical Engineering, or an equivalent degree of a suitable background, from an institution whose undergraduate program is equivalent in duration, content, and quality to that of KFUPM,
- A minimum cumulative and major Grade-Point Average (GPA) of 3.00 (on a 4-point scale),
- Achieving minimum score of 520 (PBT) or 190 (CBT) or 69 (IBT) in TOEFL, or 5.5 in IELTS and satisfy any other admission requirement by Deanship of Graduate Studies.
- Achieving an acceptable score in GRE (Quantitative), and satisfactorily meeting the University M.S. admission requirements.

If the minimum requirement in one area is not achieved, consideration is given for a provisional admission when other credentials are satisfactory.

M. Eng. Program

This program is open only for non-scholarship students. Applicants to the M. Eng. program in Mechanical Engineering must hold a B.S. degree in Mechanical Engineering or related fields from an accredited university, with a GPA not less than 2.5/4.0 or equivalent.

The applicant must satisfy the general requirements for M.S. admission set by the Deanship of Graduate Studies. If the minimum requirement in one area is not achieved, consideration is given for a provisional admission when other credentials are satisfactory.

Ph.D. Program

The Ph.D. program is designed for full-time student who is expected to engage in scholarly work on a full-time basis. The program consists of 30 graduate credit-hours of course work (beyond M.S. degree) in addition to the dissertation and seminar requirements. The maximum load for the Ph.D. student is 12 graduate credit-hours per semester and all the credited courses should be taken from 500 and 600 levels. Thus, the course work will require one and a half years, and the dissertation will require an additional year and a half. The maximum period allowed for obtaining the Ph.D. degree is five years.

- Students applying to the doctoral program must provide evidence of exceptional scholastic ability, intellectual creativity, and research motivation. The minimum requirements for admission to the Doctoral Program in the College of Graduate Studies as a regular student with full standing in Mechanical Engineering are:

- A master's degree from a university of recognized standing with a cumulative GPA of 3.0 or above (on a 4.0 scale),
- A major in mechanical engineering or evidence of suitable background for entering the fields of mechanical engineering, such as thermofluid sciences, engineering mechanics, and materials and manufacturing,

- Achieving a minimum score of TOEFL (79 IBT) or IELTS (6.5), as required by the deanship of graduate studies,
- Achieving a minimum score of GRE (quantitative) as required by the ME department, and satisfactorily meeting the university Ph.D. admission requirements.

Program Courses

The department offers a wide range of graduate courses which can be broadly categorized under four areas of concentrations:

1. **Thermofluid Sciences:** This field covers subjects of: thermodynamics, fluid mechanics, heat transfer, refrigeration and air-conditioning, energy conversion, water desalination, renewable energy, and combustion.
2. **Engineering Mechanics:** This field covers subjects of: solid mechanics, dynamics, vibrations, control, and computational mechanics.
3. **Materials & Manufacturing:** This field covers subjects of: materials-processing, advanced manufacturing techniques, mechanical behavior of materials, and various durability and performance related issues of materials in mechanical system.
4. **Renewable Energy:** This field covers subjects of: PV solar energy systems, concentrated solar power, wind energy, energy storage, and energy management.

The courses offered under each area of concentration are as follows:

Thermofluid Sciences Courses

ME 501	Numerical Methods in Mechanical Engineering
ME 505	Computational Fluid Dynamics
ME 523	Advanced Energy Conversion
ME 524	Energy Management
ME 525	Renewable Energy Management
ME 526	Wind Energy
ME 527	Carbon Capture & Utilization
ME 528	Energy Storage Systems
ME 529	Advanced Thermal Desalination
ME 531	Advanced Thermodynamics
ME 532	Advanced Fluid Mechanics I
ME 534	Conduction Heat Transfer
ME 535	Radiation Heat Transfer
ME 536	Convection Heat Transfer
ME 539	Solar Energy Utilization
ME 540	Concentrated Solar Power
ME 541	Micro-Fluidics
ME 542	PV Solar Energy Systems
ME 544	Desalination and Water Purification
ME 545	Membrane Based Desalination
ME 546	Lubrication Theory
ME 548	Combustion Phenomena
ME 549	Thermal Design of Heat Exchangers
ME 591	Special Topics in Thermofluid Sciences I
ME 605	Advanced Computational Fluid Dynamics Methods
ME 611	Statistical Thermodynamics
ME 612	Phase Change Heat Transfer and Two Phase Flow

ME 632	Advanced Fluid Mechanics II
ME 648	Combustion Emissions and Control
ME 691	Special Topics in Thermofluid Sciences II

Engineering Mechanics Courses

ME 551	Continuum Mechanics
ME 552	Advanced Dynamics
ME 553	Advanced Vibrations
ME 554	Elasticity
ME 555	Plasticity
ME 556	Nonlinear Finite Element Analysis
ME 557	Modern Control of Linear Systems
ME 558	Rotordynamics
ME 559	Random Vibrations
ME 560	Smart Materials and Structures
ME 561	Dynamics of MEMS and Microsystems
ME 562	Vibration Measurement and Analysis
ME 563	Wave Propagation in Solids
ME 564	Acoustics and Noise Control
ME 566	Micromechanics of Materials
ME 567	Advanced Robotics
ME 568	Fracture Mechanics
ME 569	Dynamics of Multibody Systems
ME 595	Special Topics in Engineering Mechanics I
ME 661	Nonlinear Systems Dynamic Analysis
ME 666	Dynamics and Control of Mechanical Systems
ME 668	Advanced Computational Mechanics
ME 695	Special Topics in Engineering Mechanics II

Materials and Manufacturing Courses

ME 571	Advanced Machining Processes
ME 572	Analysis of Manufacturing Processes
ME 573	Probabilistic Concepts in Design and Production
ME 575	Advanced Corrosion Engineering
ME 576	Tribology
ME 577	Deformation, Fatigue and Fracture of Engineering Materials
ME 578	Mechanical Properties of Engineering Polymers
ME 579	Advanced Mechanical Behavior of Materials
ME 580	Principles of Metal Forming
ME 581	Computer Integrated Manufacturing
ME 582	Design for Manufacturing
ME 585	Advanced Physical Metallurgy
ME 586	Finite Element Analysis in Metal Forming Processes
ME 587	Additive Manufacturing Engineering
ME 597	Special Topics in Materials and Manufacturing I
ME 672	Control of Manufacturing Processes
ME 675	Phase Transformations in Metals
ME 697	Special Topics in Materials and Manufacturing II

Renewable Energy Courses

ME 523	Advanced Energy Conversion
ME 524	Energy Management
ME 525	Renewable Energy Management
ME 526	Wind energy
ME 527	Carbon Capture & Utilization
ME 528	Energy Storage Systems
ME 529	Advanced Thermal Desalination
ME 531	Advanced Thermodynamics
ME 532	Advanced Fluid Mechanics-I
ME 539	Solar Energy Utilization
ME 540	Concentrated Solar Power
ME 542	PV Solar Energy Systems

Common Electives

The following general elective courses are included in the M.S. and Ph.D. programs.

ME 606	Independent Research (for M.S. program)
ME 701	Directed Research I (for Ph.D. program)
ME 702	Directed Research II (for Ph.D. program)

M.S. Program

The Master of Science (M.S.) degree requires the successful completion of core courses, elective courses, and a thesis. This program is recommended for students interested to pursue career in research and development or possibly continuing for a doctoral degree. All program options require 30 credits and a minimum cumulative GPA of 3.0 to graduate. A student will be placed on academic probation if his GPA falls below 3.0. All degree requirements must be completed within 5 semesters. There are three program options that the student select from: Thermo-fluid Sciences, Engineering Mechanics, or Materials and Manufacturing. All program options have the following requirements:

- 6 credits ME core courses
- 3 credits Math 500 level course
- 9 credits ME elective courses at 500 or 600 levels (one course can be at 400 level)
- 6 credits technical graduate courses at 500 or 600 levels
- 0 credit seminar course (ME 599)
- 6 credits independent thesis research (ME 610) supervised by a faculty member from the department with a minimum of two additional members. The thesis committee must approve a thesis proposal at least one semester before the defense date. The thesis is defended before the committee in a public examination. A thesis report must be submitted and approved by the department and the Deanship of Graduate Studies.

M.S. Core Courses for each Program Option

Thermofluid Sciences

ME 532	Advanced Fluid Mechanics I
ME 536	Convection Heat Transfer
MATH 5xx	MATH 513 (Mathematical Methods for Engineers) or MATH 560 (Applied Regression and Experimental Design)

Engineering Mechanics

ME 551	Continuum Mechanics
ME 552	Advanced Dynamics
MATH 5xx	Any MATH 500 level

Materials and Manufacturing

ME 572	Analysis of Manufacturing Processes
ME 577	Deformation, Fatigue, and Fracture of Engineering Materials
MATH 5xx	Any MATH 500 level

Renewable Energy

ME 523	Advanced Energy Conversion
ME 539	Solar Energy Utilization
MATH 5xx	MATH 513 (Mathematical Methods for Engineers) or MATH 560 (Applied Regression and Experimental Design)

Typical Degree Plan for M.S. Program

Course No.	Title	LT	LB	CR	
First Semester					
ME 5xx	Core I	3	0	3	
ME 5xx	ME Elective I	3	0	3	
MATH 5xx	MATH Course	3	0	3	
		9	**0**	**9**	**9**
Second Semester					
ME 5xx	Core II	3	0	3	
ME 5xx/6xx	ME Elective II	3	0	3	
XX 5xx/6xx	Technical Elective I	3	0	3	
ME 599	Seminar	1	0	0	
		10	**0**	**9**	**9**
Third Semester					
ME 5xx/6xx	ME Elective III	3	0	3	
XX 5xx/6xx	Technical Elective II	3	0	3	
ME 610	M.S. Thesis	0	0	IP	
		6	**0**	**6**	**6**
Fourth Semester					
ME 610	M.S. Thesis	0	0	6	
		0	**0**	**6**	**6**
Total Credit Hours					**30**

Notes:

1. Each student should select a thesis advisor in the first semester of enrollment.
2. Each student in consultation with his thesis advisor is expected to submit a detailed degree plan according to the above generic plan for approval by the department and the Deanship of Graduate Studies within the 8^{th} week of the second semester of enrollment. Students are required to adhere to the degree plan. Courses taken in conflict with the degree plan will not be counted towards the degree.
3. The order of taking the courses can be different from the order stated above but the student is encouraged to take the core courses in the first year of enrollment.
4. Core I and Core II courses correspond to the core courses for the student's program option (thermofluid sciences, engineering mechanics, or materials and manufacturing).
5. ME 5xx Elective I can be replaced with an undergraduate 400 level course relevant to the student's research area with prior approval of the advisor, the department, and the Deanship of Graduate Studies.
6. The XX 5xx/6xx technical elective I and II may be taken from any 500 or 600 level courses offered by any Department in the College of Engineering, College of Sciences, College of Computer Science and Engineering, and the Department of Architecture Engineering from the College of Environmental Design.
7. One XX 5xx/6xx technical elective can be replaced with an ME 5xx/6xx elective course if recommended by the student's advisor.

M. Eng. Program

The M. Eng. degree requires the successful completion of required core courses, elective courses, and an engineering project. The requirements for the Master's in engineering degree must be completed within a total period of 5 semesters. Each student admitted to the M. Eng. program in Mechanical Engineering can select one of four program options: i) Thermofluid Sciences, ii) Engineering Mechanics, iii) Materials and Manufacturing, or iv) Renewable Energy. The program requires the successful completion of the followings:

- 9 credits ME core courses
- 3 credits course from the Business School at 500 level
- 9 credits ME elective courses at 500 or 600 levels (one course can be at 400 level)
- 6 credits technical graduate courses at 500 or 600 levels
- 3 credits engineering project (ME 600) supervised by a faculty member from the department. A final technical report should be submitted at the end of the work and it must be approved by the Graduate Committee of the department.

M. Eng. Core Courses for each Program Option

Thermofluid Sciences

ME 531	Advanced Thermodynamics
ME 532	Advanced Fluid Mechanics I
ME 536	Convection Heat Transfer

Engineering Mechanics

ME 551	Continuum Mechanics
ME 552	Advanced Dynamics
ME 553	Advanced Vibrations

Materials and Manufacturing

ME 572	Analysis of Manufacturing Processes
ME 577	Deformation, Fatigue, and Fracture of Engineering Materials
MSE 5xx	MSE 501, MSE 502, or MSE 503

Renewable Energy

ME 523	Advanced Energy Conversion
ME 528	Energy Storage Systems
ME 539	Solar Energy Utilization

Typical Degree Plan for M. Eng. Program

Course No.	Title	LT	LB	CR	
First Semester					
ME 5xx	Core I	3	0	3	
ME 5xx	ME Elective I	3	0	3	
		6	**0**	**6**	**6**
Second Semester					
ME 5xx	Core II	3	0	3	
ME 5xx/6xx	ME Elective II	3	0	3	
		6	**0**	**6**	**6**
Third Semester					
ME 5xx	Core III	3	0	3	
ME 5xx/6xx	ME Elective III	3	0	3	
		6	**0**	**6**	**6**
Fourth Semester					
XX 5xx	500 level course from the Business School	3	0	3	
XX 5xx/6xx	Technical Elective I	3	0	3	
		6	**0**	**6**	**6**
Fifth Semester					
XX 5xx/6xx	Technical Elective II	3	0	3	
ME 600	Engineering Project	0	0	3	
		3	**0**	**6**	**6**
Total Credit Hours					**30**

Notes:

1. Each student should select a project advisor in the first semester of enrollment.
2. Each student is expected to submit his detailed degree plan according to the above generic degree plan for approval by the department and the Deanship of Graduate Studies within the 8th week of the second semester of enrollment. Students are required to adhere to the degree plan. Courses taken in conflict with the degree plan will not be counted towards the degree.
3. The order of taking the courses can be different from the order stated above but the student is encouraged to take the core courses as early as possible.
4. Core I, Core II, and Core III courses correspond to the core courses for the student's program option (Thermofluid Sciences, Engineering Mechanics, Materials and Manufacturing, or Renewable Energy).
5. ME 5xx Elective I can be replaced with an undergraduate 400 level course to be taken with the approval of the advisor, the department, and the Deanship of Graduate Studies.
6. ME 5xx/6xx Elective II, III and IV courses should be taken from 500 and 600 level courses. The XX 5xx/6xx technical electives could be taken from any 500 or 600 level courses offered by any department in the College of Engineering, College of Sciences, College of Computer Science and Engineering, and the Department of Architecture Engineering from the College of Environmental Design.
7. One XX 5xx/6xx technical elective can be replaced with an ME 5xx/6xx elective course if recommended by the student's advisor.

Ph.D. Program

The Ph.D. program in ME is designed for full-time student. The Ph.D. degree requires the graduate student to complete 30 credits course work beyond the M.S. degree with a minimum GPA of 3.0, satisfactorily pass a comprehensive examination covering his major and minor area of study, a seminar, and present a 12 credits worth of research documented in a dissertation. The maximum load for the Ph.D. student is 12 graduate credit-hours per semester and all the credited courses should be taken from 500 and 600 levels. The maximum period allowed for obtaining the Ph.D. degree is five years. Each graduate student admitted to the Ph.D. program should select a major and a minor research areas. A major area must be one of the three research areas offered by the department (Thermofluid Sciences, Engineering Mechanics, and Materials & Manufacturing). A minor area is defined as an advanced topic offered by any department in the College of Sciences, all departments in the College of Engineering and College of Computer Science and Engineering, and the department of Architecture Engineering from the college of Environmental Design. The degree requirements are:

- 21 credits ME courses in a major area
- 9 credits technical elective courses in a minor area
- 0 credit seminar (ME 699)
- 3 credits Pre-Dissertation research project (ME 711) supervised by a faculty member from the department leading to a Ph.D. proposal approved by the Ph.D. committee, the department, and the Deanship of Graduate Studies.
- 9 credits of Ph.D. dissertation (ME 712)

Comprehensive Examination (CE)

The Graduate School of KFUPM requires all doctoral students to pass a Comprehensive Exam by the end of the second year from the student's enrollment in the Ph.D. program. In Mechanical Engineering, the comprehensive examination will normally be given during the third semester after the student enrollment in the Ph.D. program and consists of both a written part (80%) and an oral part (20%).

Major CE topics for Thermofluid Sciences

- Advanced Fluid Mechanics (Typical topics covered in ME 311 and ME 532)
- Heat Transfer (Typical topics covered in ME 315, ME 535, and ME 536)
- Advanced Thermodynamics (Typical topics covered in ME 203, ME 204, and ME 531)

Major CE topics for Engineering Mechanics

- Continuum Mechanics (Typical topics covered in ME551)
- Advanced Dynamics or Vibrations (Typical topics covered in ME552 or ME553)

- Control (Typical topics covered in ME557)

Major CE topics for Materials and Manufacturing

- Analysis of Manufacturing Processes (typical topics covered in ME572)
- Deformation, Fatigue, and Fracture (typical topics covered in ME577).
- Materials or Manufacturing Topic (based on the recommendation of the student's advisor).

Ph.D. Dissertation

A candidate who successfully passes the Comprehensive Examination may proceed with his research work under the supervision of his dissertation advisor and in consultation with his dissertation committee. A Ph.D. student should select his dissertation advisor during the first semester of his enrollment to the Ph.D. program. A dissertation committee must be formed for each student upon the recommendation of the Department and approval of the Dean of the College of Graduate Studies. The membership of the committee must be in an odd number with a minimum of 5 members. The committee includes: the dissertation advisor (Chairman), Mechanical Engineering faculty members from the specified area of research, and one faculty member from outside the Department in a related area of research. After successful completion of the course work and the comprehensive exam, the student will register for his Ph.D. Pre-dissertation (ME 711). After passing the Ph.D. Pre-dissertation, the student can register for his Ph.D. Dissertation (ME 712). Upon completion of his research work, the candidate is required to defend his dissertation before the dissertation committee in public. The Ph.D. degree will be conferred upon the recommendation of the dissertation committee and the department, and approval by the Deanship of Graduate Studies.

Typical Degree Plan for Ph.D. Program

Course No.	Title	LT	LB	CR	
First Semester					
ME 5xx/6xx	ME Elective I	3	0	3	
ME 5xx/6xx	ME Elective II	3	0	3	
ME 5xx/6xx	ME Elective III	3	0	3	
		9	**0**	**9**	**9**
Second Semester					
ME 5xx/6xx	ME Elective IV	3	0	3	
ME 5xx/6xx	ME Elective V	3	0	3	
ME 5xx/6xx	ME Elective VI	3	0	3	
		9	**0**	**9**	**9**
Third Semester					
ME 5xx/6xx	ME Elective VII	3	0	3	
XX 5xx/6xx	Technical Elective I	3	0	3	
XX 5xx/6xx	Technical Elective II	3	0	3	
ME 699	Seminar	1	0	0	
		10	**0**	**9**	**9**
Fourth Semester					
XX 5xx/6xx	Technical Elective III	3	0	3	
ME 711	Ph.D. Pre-Dissertation	0	0	3	
		3	**0**	**6**	**6**
Fifth Semester					
ME 712	Ph.D. Dissertation	0	0	IP	
		0	**0**	**0**	**0**
Sixth Semester					
ME 712	Ph.D. Dissertation	0	0	9	
		0	**0**	**9**	**9**
Total Credit Hours					**42**

Notes:

1. Each Ph.D. student should select a dissertation advisor in the first semester of enrollment.
2. Each student is expected to submit his detailed degree plan according to the above generic degree plan for approval by the Department and the Deanship of Graduate Studies within the 8^{th} week of the second semester of enrollment. Students are required to adhere to the regulations of the degree plan. Courses taken in conflict with the degree plan will not be counted towards the degree.
3. The technical electives could be taken from any 500 or 600 level courses offered by any department in the College of Engineering, College of Sciences, College of Computer Science and Engineering, and the Department of Architecture Engineering from the College of Environmental Design.
4. One of the technical elective courses must be taken as 500 or 600 level Math course if the student has not taken a graduate course in Math in his M.S. degree.
5. ME 701 (Directed Research I) and ME 702 (Directed Research II) are considered as ME 5xx/6xx electives.

Course Descriptions

ME 501 Numerical Methods in Mechanical Engineering (3-0-3)

Concepts of consistency, stability, and convergence of numerical schemes. Initial and boundary value problems for ordinary differential equations. Various finite difference and finite element methods and their applications to fundamental partial differential equations in engineering and applied sciences. Case studies.

Prerequisite: Graduate standing (not to be taken for credit with MATH 574)

ME 505 Computational Fluid Dynamics (3-0-3)

Governing equations of fluid dynamics (CFD). Introduction to CFD. Grid generation, discretization. Numerical approximations: finite difference and finite volume methods, CFD tools: adapted programs and commercially available general purpose packages. Applications to incompressible and compressible fluid flow.

Prerequisite: Graduate standing (not to be taken for credit with CHE 505)

ME 523 Advanced Energy Conversion (3-0-3)

Primary Sources of Energy. Fossil fuels, Bio-fuels, Chemical Reactions. Power cycles. Carbon capture. Renewable energy: Solar energy with emphasis on solar thermal and solar PV, wind energy and geothermal energy. Fuel cells: types and performance. Energy storage and Fuel reforming. Nuclear energy: components, reactor types and fuel cycles.

Prerequisites: Graduate standing

ME 524 Energy Management (3-0-3)

Energy management, energy audit and energy efficiency. Energy management and optimization in thermal utilities: fuel combustion, boilers, steam systems cogeneration, furnaces, waste heat recovery, insulation and refractory, HVAC and refrigeration systems, cooling towers, heat exchangers. Energy management and optimization in mechanical and electrical utilities: electrical systems, pumping systems, electric motors, compressed air systems, lighting systems, diesel and gas generating systems, and fans and blowers. Energy performance assessment: economics and financial analyses, environmental, health and safety. Case Studies.

Prerequisite: Graduate standing

ME 525 Renewable Energy Management (3-0-3)

Energy Resources and Energy Systems, Photovoltaic and Solar Thermal Systems, Wind Energy, Hydro Power, Bioenergy and Geothermal Energy, Hybrid Renewable Energy systems, Energy Efficiency and Environment, Energy Economics and Markets, Energy Policy, Legislation and Management, Decentralized Energy Systems Planning, Studying the feasibility of renewable energy projects using available software such as RETScreen, HOMER.

Prerequisite: Graduate standing

ME 526 Wind Energy (3-0-3)
Wind power resource assessment, Offshore wind energy and meteorological measurements, Probabilistic methods for wind energy, Introduction to micrometeorology for wind turbine systems, Aerodynamics and control of wind turbines, Structural analysis and mechanical design of wind turbines, Composite materials and fibers, Design and dynamics of wind turbine towers, Integration of wind energy in power system and power grid analysis, Planning and development of wind farms, Introducing simulation software in wind energy such as Windpro and HOMER.
Prerequisite: Graduate standing

ME 527 Carbon Capture & Utilization (3-0-3)
Introduction, the atmosphere, the climate, Carbon cycle: the biological carbon cycle, the role of oceans in the carbon cycle, the inorganic carbon cycle, A box model for the global carbon cycle, the future carbon cycle, Introduction to carbon capture, Gas separations, Absorption, Adsorption, Novel materials for carbon capture, membranes, Transportation and related safety considerations, CO_2 Utilization Options: Challenges and Opportunities, Enhanced oil/gas recovery, CO_2 as feedstock for production of fuels and chemicals, Non-geologic storage of CO_2 (mineralization), Desalination and water production.
Prerequisite: Graduate standing

ME 528 Energy Storage Systems (3-0-3)
Power generation supply and demand, Importance of energy storage, Needs for energy storage and storage alternatives, Storage of thermal mechanical, and electrical energy, Thermal energy storage: Thermal energy storage in solar systems; Thermal energy storage in air conditioning systems; Thermal energy storage with phase change material, Chemical Energy storage (solar fuel reforming). Mechanical energy storage: Spin Wheels, pumps, turbines and waste heat recovery (e.g. Air compression, pump (hydro) power, spin wheels in various sizes.). Electrochemical storage of electrical energy: Important battery technologies and hydrogen technologies (e.g. Lead batteries, various Li-ion batteries, different hydrogen storage, and various fuel cells and supercapacitors). Integration of energy storage media, its effects on the bulk power system: design tradeoffs; and environmental impacts; cost; reliabilities; efficiencies.
Prerequisite: Graduate standing

ME 529 Advanced Thermal Desalination (3-0-3)
Seawater composition, classification of desalination systems, desalination using renewable energy sources such as solar stills and Humidification Dehumidification systems with various layouts, Economic analysis of desalination processes, Single effect evaporation, Multiple effect evaporation, Multistage flash distillation, once through Multistage flash systems, brine mixing and brine recirculation Multistage flash, thermal vapor compression, Membrane distillation, New trends and fouling in desalination systems.
Prerequisite: Graduate standing

ME 531 Advanced Thermodynamics (3-0-3)
Fundamentals of classical thermodynamics; First and Second law. Postulatory thermodynamics. State relationships for real gasses and liquids. Thermodynamic properties of pure fluids and mixtures. Phase equilibrium. Chemically reacting systems. Chemical equilibrium. Exergy analysis of non-reacting and reacting systems. Applications.
Prerequisite: Graduate standing

ME 532 Advanced Fluid Mechanics I (3-0-3)
Conservation equations for viscous fluids. Ideal fluid flow. Boundary layer concept. Navier-Stokes equations and some exact solutions. Stokesian flow. Laminar boundary layer equations and methods of solution. von Karman momentum integral equation. Theory of stability of laminar flows. Introduction to turbulent flow.
Prerequisite: Graduate standing

ME 534 Conduction Heat Transfer (3-0-3)
Thermal conductivity and law of thermodynamic equilibrium. General heat conduction equation. Boundary conditions involving specified temperature and heat flux, convection and gray body thermal radiation. Thermal circuit concept. Steady one-dimensional conduction: composite walls, heat source systems, extended surfaces. Steady multi-dimensional conduction applications. Unsteady one – and multi-dimensional heat conduction applications. Phase change with moving boundaries. Numerical and classical analytical solution methods.
Prerequisite: Graduate standing

ME 535 Radiation Heat Transfer (3-0-3)
Radiation from a black body. Definitions and estimation of radiative properties of non-black surfaces. Radiative properties of real materials. Radiation exchange between black and gray surfaces. Thermal radiation between non-diffuse gray surfaces. Radiation exchange between gases and enclosures. Combined convection and radiation heat transfer. Radiative behavior of windows, coatings, and solids. Applications and numerical solution methods.
Prerequisite: Graduate standing

ME 536 Convection Heat Transfer (3-0-3)
Convection systems. Derivation of conservation equations and solutions for laminar and turbulent boundary layer flows. Forced convection, internal and external flows. Natural convection. Special topics and applications.
Prerequisite: ME 532 or consent of the instructor

ME 539 Solar Energy Utilization (3-0-3)
Design consideration of various concentrating collectors for thermal and photovoltaic applications. Solar thermal/electric power conservation. Solar thermal energy storage. Solar thermal design methods: f-chart utilizability. Solar space conditioning design and computer simulation models such as TRNSYS. Economic considerations. Solar desalination and other applications. Design projects in selected areas.
Prerequisite: Graduate standing

ME 540 Concentrated Solar Power (3-0-3)
Solar energy and CSP technologies. Design, modeling and performance analysis and optimization of different CSP technologies: Solar tower; solar dish, parabolic trough collectors; linear Fresnel reflectors, Design and performance analysis of thermal storage and chemical storage (solar fuel reforming systems), Modeling and performance analysis of solar power plants; integrated solar gas turbine; cogeneration; and combined cycles plants, Solar assisted cooling systems, Integrated CSP systems modeling and performance analysis software.
Prerequisite: Graduate standing

ME 541 Micro-Fluidics (3-0-3)
Definitions, commercial and research aspects, fluid mechanics at microscale level, experimental flow characterization at microscale, flow in micro-channels, electrokinetic flows and applications, micro-pumps and micro-valves, micro-flow sensors, fabrication techniques for micro-fluidics, introduction to lab-on-chip design and project.
Prerequisite: Graduate standing

ME 542 PV Solar Energy Systems (3-0-3)
Advanced knowledge of different PV technologies and systems: fundamental science with practical implementation, PV cell and module materials, sizing and optimization of PV systems, energy yield estimation and assessment of its performance under different conditions. The design, technical and economic feasibility of stand-alone photovoltaic systems.
Prerequisite: Graduate standing

ME 544 Desalination and Water Purification (3-0-3)
Water purification by desalination and filtration. Fundamentals of thermodynamics and transport processes. Least work of separation and maximum GOR. Technologies of existing desalination systems. Energy efficiency of desalination systems. Nanofiltration and emerging technologies for desalination. Rain water and fog collection and treatment. Selection and design of a cistern water systems. Life cycle water costs.
Prerequisite: Graduate standing

ME 545 Membrane Based Desalination (3-0-3)
Clean water global challenge. Review of desalination technologies. Introduction to RO desalination, membrane materials and characterization, membrane transport theory, concentration polarization and membrane fouling, membranes and modules, RO system design and operation technology.
Prerequisite: Graduate standing

ME 546 Lubrication Theory (3-0-3)
Development of Reynolds Equation from Navier Stokes equations to study the hydrodynamics lubrication theory as the basis for bearing design; applications to simple thrust and journal bearings and pads of various geometries; hydrostatic lubrication, floating ring bearings, compressible gas lubrication, grease lubrication, dynamically loaded bearings, half speed whirl and stability.
Prerequisite: Graduate standing

ME 548 Combustion Phenomena (3-0-3)

Thermodynamics and thermochemistry of combustion; chemical kinetics and mechanisms, dissociation and equilibrium, transport equations for reacting flows, autoignition phenomena, flame stability, laminar premixed and diffusion flames, spray (droplet) combustion, turbulent combustion, detonation and deflagrations, combustion diagnostics systems. Applications in IC engines, industrial furnaces, and gas turbines.

Prerequisite: Graduate standing

ME 549 Thermal Design of Heat Exchangers (3-0-3)

Classification of a variety of heat exchangers, various methods for the exchanger analysis and performance evaluation, pressure drop analysis including header design and flow maldistribution, fouling and its impact on the exchanger performance and life-cycle analysis. Special design considerations for regenerators, plate-fin, tube-and-frame, shell-and-tube, reboilers, condensers, evaporators, and direct-contact heat exchangers.

Prerequisite: Graduate standing

ME 551 Continuum Mechanics (3-0-3)

Tensors, indicial notation and transformation of coordinates. Stresses, principal stresses and Mohr's circle. Deformation and strain. Velocity fields and compatibility conditions. Constitutive equations. Isotropy. Mechanical properties of solids and fluids. Field equations: applications to elasticity, viscoelasticity, plasticity and fluid mechanics.

Prerequisite: Graduate standing (not to be taken for credit with CE 518)

ME 552 Advanced Dynamics (3-0-3)

Fundamentals of Newtonian dynamics. Hamilton's Principle and Lagrange's equations. Relativistic dynamics. Central force motion and stability of circular orbits. Rigid body dynamics. Euler's equations of motion, Euler angles, gyroscopic motion, spinning projectile, Hamilton's equations and phase space. Hamilton-Jacobi equation.

Prerequisite: Graduate standing

ME 553 Advanced Vibrations (3-0-3)

Review of single-degree of freedom oscillator: formulation using generalized stiffness, inertia and damping. Damping mechanisms: viscous, friction and complex. Response to transient and general excitations. Multiple-degree of freedom systems: formulation and methods of solution. Direct stiffness, influence coefficients and variational approaches. Eigenvalue analysis. Vibration of continuous systems. Approximation methods of continuous systems. Modal reduction technique.

Prerequisite: Graduate standing

ME 554 Elasticity (3-0-3)

Plane stress, plane strain and biharmonic solutions. Problem formulation in Cartesian and polar coordinates. Polynomial, Fourier series and complex variable solutions. Energy theorems and variational techniques. Three-dimensional elasticity. Saint-Venant torsion and bending theory. Navier's equation and Galerkin vector.

Prerequisite: Graduate standing

ME 555 Plasticity (3-0-3)

The physics of plasticity: Plastic deformation, Stress-Strain relations, temperature and rate dependence, and crystal plasticity. Constitutive theory: Viscoplasticity, rate-independent plasticity, yield criteria, flow and hardening rules, uniqueness theorems and limit analysis. Problems in contained plastic deformation: torsion of prismatic bars, thick-walled cylinders, and bending of beams. Problems in plastic flow and collapse. Large deformation plasticity. Numerical methods in plasticity.

Prerequisite: Graduate standing

ME 556 Nonlinear Finite Element Analysis (3-0-3)

Finite element formulation. Small-deformation elastic-plastic analysis. Finite-strain formulation. Implementation of the finite-strain formulation. Practical applications in metal forming processes and structural component design.

Prerequisite: ME 551 or consent of the instructor

ME 557 Modern Control of Linear Systems (3-0-3)

Overview of state-space modeling of linear systems. Stability of time-invariant linear systems. Controllability and observability conditions. Formulation of tracking and regulator problems. Optimal linear state-feedback control. The linear optimal regulator problems. Observers, full-order observers and the optimal observer design.

Prerequisite: Graduate standing

ME 558 Rotordynamics (3-0-3)

The basic rotor components: disk, shaft and bearings. Simple rotor models, natural frequencies, Campbell diagram, instability, and mass unbalance. Finite element modeling of rotor components. Dynamic modal characteristics of rotors, modal transformations and reduced-order equations. Numerical solution of the rotor equations.

Prerequisite: ME 552 or consent of the instructor

ME 559 Random Vibrations (3-0-3)

Introduction to random vibrations and stochastic processes. Spectral analysis and frequency response methods. Auto correlation, Cross correlation and Power-spectral density. Random load transmission. Vibration data processing. Digital and fast Fourier transform. Response of continuous systems to random excitation. Wavelet analysis.

Prerequisite: ME 553 or consent of the instructor

ME 560 Smart Materials and Structures (3-0-3)

Analysis, design and implementation of smart structures and systems. Modeling of beams and plates with induced strain actuation, piezoelectric ceramics and polymers, shape memory alloys, and electro-rheological fluids. Piezoelectric and magnetostrictive sensors and actuators, and fiber optic sensors. Integration mechanics. Damage detection and repair. Applications.

Prerequisite: Graduate standing

ME 561 Dynamics of MEMS and Microsystems (3-0-3)
Modeling and characterization of MEMS structures: static analysis, free undamped vibration, free damped vibration in coupled fields (structural, electrostatic, fluidic and thermoelastic), forced vibration and reduced-order modeling. Introduction to perturbation and nonlinear dynamics.
Prerequisite: Graduate standing

ME 562 Vibrations Measurement and Analysis (3-0-3)
Analysis of lumped and distributed parameter systems. Concepts of torsional vibration. Resonances. Frequency response and transfer function methods. Modal analysis. Mathematical modeling using experimental data. Digital Fourier analysis and Fast Fourier Transform. Instrumentation, transducer measurement considerations, data acquisition, signal processing and vibration data format. Typical vibration problems. Fault diagnosis techniques of rotating machinery. Basic balancing of rotors. Resonance and critical speed testing. Machine analysis case studies.
Prerequisite: ME 553 or consent of the instructor

ME 563 Wave Propagation in Solids (3-0-3)
Theory and principles of elastic wave propagation in solids. Reflection, refraction and transmission of plane waves. Dispersion and scattering. Guided wave modes. Analytical and numerical solutions. Applications of ultrasonics to quantitative non-destructive testing (NDT).
Prerequisite: Graduate standing

ME 564 Acoustics and Noise Control (3-0-3)
Analysis and measurement of sound and vibration as applied to noise control. Review of fundamentals and principles, noise generators. Noise control: noise criteria, sound absorption and insulation, noise barriers, acoustic enclosures and silencers. Vibration isolation criteria, damping materials and vibration isolating mounts. Machine element noise, fan and flow induced noise, combustion and furnace noise, fluid piping noise, compressor and pump noise, and internal factory noise.
Prerequisite: Graduate standing

ME 566 Micromechanics of Materials (3-0-3)
Fundamental equations of elasticity and plasticity. General theory of eigenstrains including Fourier series and integrals and Green's function, Inhomogeneities and dislocations. Eshelby theory, Deformation of metallic alloys – Mori-Tanaka theory. Deformations of metal matrix and ceramic matrix – Brown dispersion hardening and residual stresses. Pure and ductile damage.
Prerequisite: ME 551 or consent of the instructor

ME 567 Advanced Robotics (3-0-3)
Advanced programming and hardware concepts related to working robots, networking of robots, 3-D kinematics, trajectory generation and compliance analysis. Dynamics and control of robots. Assembly operations and machine vision. Industry automation, safety procedures and standards.

Prerequisite: Graduate standing

ME 568 Fracture Mechanics (3-0-3)

Fracture modes and stress fields at the crack tip. Stress intensity factors. Griffith and Irwin theories. Crack initiation and propagation. Fracture tests and fracture toughness. Fatigue crack growth. Elastic-plastic fracture mechanics. Mechanisms and mechanics of fractures in engineering components. Numerical methods in fracture mechanics.

Prerequisite: Graduate standing

ME 569 Dynamics of Multibody Systems (3-0-3)

Definition of a multibody system. Mechanical joints and their kinematic constraints. Equations of motion for a multibody system: the constrained form of Lagrange's equation, constrained and unconstrained equations of motion, Lagrange multipliers, joint reaction forces, coordinate partitioning, and the Lagrangian form with embedded constraints. Dynamics of spatial multibody systems: coordinate transformations using Euler parameters and formulation of the joint constraints. Introduction to computational methods in dynamics. The mechanics and deformable bodies: rods, beams and blades. Formulation of the rigid-elastic multibody equations of motion and constrained equations. Computational techniques for deformable mechanisms and multibody flexible systems. Applications.

Prerequisite: ME 552 or consent of the instructor

ME 571 Advanced Machining Processes (3-0-3)

Non-conventional and hybrid processes based on high thermal energy sources including laser beam, electric discharge, electron beam, and plasma arc; mechanical processes including abrasive jet, water jet, ultrasonic, and hybrids; chemical and electrochemical processes. Design, quality, integrity of machined products, and economics of advanced machining.

Prerequisite: Graduate standing

ME 572 Analysis of Manufacturing Processes (3-0-3)

The first half of the course covers different theories of machining of metals, modeling of forces in machining, effect of friction and temperature, cutting tools design and tool materials, machining economics, in addition to analysis of grinding processes. The second half introduces modeling of cold and hot metal deformation, yielding criteria, ideal deformation, slab analysis and upper bound analysis for different sheet and bulk deformation processes.

Prerequisite: Graduate standing

ME 573 Probabilistic Concepts in Design and Production (3-0-3)

Probabilistic concepts and distributions. Linear and nonlinear combination of random variables in probabilistic design. Error propagation and tolerance analysis. Stress-strength interference theory and reliability computations. Monte Carlo simulation. Products and systems failure rates and reliability models. Reliability testing and failure data analysis from complete and censored data using maximum likelihood estimation, method of moments, and graphical techniques using probability papers and computer software. Accelerated life testing, Reliability growth models and analysis. Preventive and corrective maintenance.

Prerequisites: Graduate standing

ME 575 Advanced Corrosion Engineering (3-0-3)
Corrosion thermodynamics and kinetics. Pourbaix diagrams, mass transfer and corrosion. Effect of environmental factors on major forms of corrosion. Anodic and cathodic protection of metals. Organic and nonmetallic coating. Testing, monitoring and inspection. Materials selection for corrosion resistance.
Prerequisite: Graduate standing

ME 576 Tribology (3-0-3)
Classification of wear modes. Adhesion. Abrasion. Rolling-sliding wear, Erosion, Corrosion, Combined wear modes. Friction and heat transfer calculations. Wear models and testing. Design of wear resistant systems. Selection of wear resistant materials.
Prerequisite: Graduate standing

ME 577 Deformation, Fatigue and Fracture of Engineering Materials (3-0-3)
Review of basic mechanical testing, elastic deformation, stress transformation and static failure theories. Fracture mechanics. Stress-based fatigue for smooth and notched members. Fatigue crack growth. Modeling and analysis of plastic deformation. Strain-based fatigue.
Prerequisite: Graduate standing

ME 578 Mechanical Properties of Engineering Polymers (3-0-3)
General introduction to polymers and their applications. Types of mechanical behavior. Hookean and rubber elasticity. Plastic deformation. Fracture. Linear viscoelasticity. Dynamic mechanical behavior and testing. Experimental methods. Mechanical properties of polymeric composites.
Prerequisite: Graduate standing

ME 579 Advanced Mechanical Behavior of Materials (3-0-3)
Point defects and its effects on mechanical properties. Theory and characteristics of dislocations. Grain and twinning boundaries in plastic deformation, geometry of deformation and work-hardening, strengthening mechanisms. Microscopic aspects of fracture, modes of fracture. Deformation at elevated temperatures, superplasticity, deformation maps.
Prerequisite: Graduate standing

ME 580 Principles of Metal Forming (3-0-3)
Stress-strain behavior of metals. Introduction to plasticity. Homogeneous and redundant works. Plastic anisotropy. Slab methods. Upper-bound analysis. Slip line field theory. Open and closed die forging. Extrusion of metals. Mechanics of wire drawing, hot and cold rolling, stretch forming, sheet bending. Analysis of deep drawing, tube drawing and tube making.
Prerequisite: Graduate standing

ME 581 Computer Integrated Manufacturing (3-0-3)
A study of the impact of computers and automation on discrete parts manufacturing. Flexible manufacturing and assembly equipment. CAD/CAM concepts and applications. Process

planning and manufacturing scheduling. Materials handling. Robotics. Quality assurance. Tooling and fixtures for CNC systems.
Prerequisite: Graduate standing

ME 582 Design for Manufacturing (3-0-3)
Product design for manufacturing, assembly and sustainability. Fundamentals of concurrent engineering, product specification and standardization, materials selection and manufacturability, cost analysis, designing for quality, and sustainability.

Prerequisite: Graduate standing

ME 585 Advanced Physical Metallurgy (3-0-3)
Review of structure of metals. Dislocation, plastic deformations, and grain boundaries. Vacancies, annealing, solid solutions, phase diagrams, diffusion, solidification of metals. The Fe-C alloy system.
Prerequisite: Graduate standing

ME 586 Finite Element Analysis in Metal Forming (3-0-3)
General introduction to FEM and metal forming processes. Basic formulation for elastic deformation. Introduction to plasticity and viscoplasticity. Introduction to finite element nonlinear analysis. Small-deformation elastic-plastic analysis. Finite-strain formulation for metal forming analysis. Implementation of the finite-strain formulation. Practical applications; plane strain problems of rolling and bending, axisymmetric isothermal forging, steady-state processes of extrusion and drawing. Sheet metal forming. Thermo-viscoplastic analysis. Future developments.
Prerequisite: ME 551 or consent of the instructor

ME 587 Additive Manufacturing Engineering (3-0-3)
Additive manufacturing (AM) or 3D printing processes for metallic alloys, polymers, ceramics, and composites: vat photopolymerization, powder bed fusion, extrusion-based systems, binder and materials jetting, sheet amination, directed energy deposition, and direct write. Basic interrelations among AM processing parameters, parts microstructures, and mechanical properties. Process selection, design for AM, and the impact of AM in revolutionizing manufacturing industries. Reverse engineering technology including digitizing processes through optical scanning and laser scanning.
Prerequisite: Graduate standing

ME 591 Special Topics in Thermofluid Sciences I (3-0-3)
Advanced topics are selected from thermofluid area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering the course.
Prerequisite: Graduate standing

ME 595 Special Topics in Engineering Mechanics I (3-0-3)
Advanced topics are selected from engineering mechanics area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval

of the Departmental Graduate Committee and the Graduate Council must be secured before offering the course.

Prerequisite: Graduate standing

ME 597 Special Topics in Materials & Manufacturing I (3-0-3)

Advanced topics are selected from materials and manufacturing area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering the course.

Prerequisite: Graduate standing

ME 599 Seminar (1-0-0)

Graduate students working towards M.S. degree are required to attend the seminars given by faculty and visiting scholars. Additionally, each student must present at least one seminar on a timely research topic. Among other things, this course is designed to give the student an overview of research in the department, and a familiarity with the research methodology, journals and professional societies in his discipline. Graded on a Pass or Fail basis.

Prerequisite: Graduate standing

ME 600 Engineering Project (0-0-3)

The course is offered on a student-to-faculty basis. For a student to register in such a course with a specific faculty member, a clear Research Plan of the intended research work during the course is required to be approved by the Graduate Committee of the department and reported to the Deanship of Graduate Studies. At the end of the course, the student should submit a final report.

Prerequisite: Prior arrangement with a course instructor. Only offered for M. Eng. students.

ME 605 Advanced Computational Fluid Dynamics Methods (3-0-3)

Overview of various computational fluid dynamics methods to date, relevance to continuum and non-continuum fluid dynamics. Introduction to Lattice Boltzmann Method (LBM), basics of Kinetic theory of particles, Boltzmann equation. Development of LBM for diffusion equation, diffusion-convection equations, non-isothermal flows, different relaxation techniques. Introduction to Molecular Dynamics Computational Method. Applications and Code Development.

Prerequisite: ME 505 or consent of the instructor

ME 606 Independent Research (3-0-3)

Course to be offered on a student-to-faculty basis. For a student to register in such a course with a specific faculty member, a clear Research Plan of the intended research work during the course is required to be approved by the Graduate Committee of the department and reported to the Deanship of Graduate Studies. At the end of the course, the student should submit a report and present his work to the Department Graduate Committee publicly.

Prerequisite: Graduate standing

ME 610 M.S. Thesis (0-0-6)

Formal record of student commitment to master's thesis research under the guidance of a faculty advisor. Student to defend his thesis in public and in the presence of a committee of at least 3 faculty members.

Co-requisite: ME 599

ME 611 Statistical Thermodynamics (3-0-3)

Basic concepts and principles of statistical thermodynamics including statistical mechanics, probability theory, quantum mechanics, kinetic theory, and thermo-physical and transport properties. Basic concepts and principles of gas dynamics for compressible flow within normal temperature ranges. In depth coverage of chemical thermodynamics including chemical equilibrium and chemical kinetics.

Prerequisite: ME 531 or consent of the instructor

ME 612 Phase Change Heat Transfer and Two Phase Flow (3-0-3)

Fundamental mechanisms of evaporation and condensation. Bubble equilibrium, nucleation criteria. Pool and flow boiling models and correlations. Two-phase flow models and governing equations. Flow regime transitions. Pressure drop calculations. Measurement techniques. Drop-wise and film-wise condensation, flow and non-flow systems. Enhanced surface boiling and condensation.

Prerequisite: ME 536 or consent of the instructor

ME 632 Advanced Fluid Mechanics II (3-0-3)

Stability of laminar flow and causes of transition to turbulence. Conservation equations and Reynolds stresses. Turbulent boundary layer equations, integral and other methods of solution. Free turbulence, wakes and jets. Statistical analysis; scales of turbulence, correlation functions, spectra. Measuring techniques.

Prerequisite: ME 532 or consent of the instructor

ME 648 Combustion Emissions and Control (3-0-3)

Combustion emissions, mechanisms of emissions formation, effects of design and operating parameters on emission formation in various energy conversion devices including diesel engine, SI engine, and GT engine, emissions from solid fuels, heavy oils, gaseous fuels, and biofuels, effect of fuel quality on emissions, emission control and instrumentation.

Prerequisite: ME 548 or consent of the instructor

ME 661 Nonlinear Systems Dynamic Analysis (3-0-3)

Fundamentals of quantitative and qualitative analysis techniques of nonlinear dynamic systems. Elements of nonlinear systems. Phase plane diagrams, stability and bifurcation of equilibrium and limit cycles, attractors, Lyapunov stability and Poincaré map. Harmonic balance, K-B averaging, Linstedt-Poincaré and multiple-time scales methods. Sub-harmonic, super-harmonic, combination and internal resonances. Parametrically excited systems, Mathieu's equation, and Floquet theory. One- and two-dimensional maps, structural stability and chaotic attractors, correlation dimensions, Lyapunov exponents and Melnikov's function. Trends in current research.

Prerequisite: ME 552 or consent of the instructor

ME 666 Dynamics and Control of Mechanical Systems (3-0-3)

Dynamics of mechanical systems. Mechanics of ground and airborne vehicles. Introduction to inertial guidance and navigation. Nonlinear control systems: fundamentals of Lyapunov theory, describing function analysis, feedback linearization, and sliding-mode control. Optimal control design. Improving system response via control techniques. Case studies via computer simulations.

Prerequisite: ME 552 or consent of the instructor

ME 668 Advanced Computational Mechanics (3-0-3)

PDEs representing physical/mechanical phenomena. Time-stepping (courant condition, diffusion condition). Hardening and post softening mesh convergence. Rate-independent and Rate-dependent solving schemes. Strain-localization (Indentation). Non-local modeling involving strain-localizations. Material length-scales, Coupled multi-physics, multi-scale problems.

Prerequisite: ME 551 or consent of the instructor

ME 672 Control of Manufacturing Processes (3-0-3)

Application of computer-based control system techniques to batch manufacturing processes. A brief review of control concepts and servomechanisms with an in-depth study of modeling and control problems associated with several manufacturing processes. These include, but not restricted to, metal cutting, metal forming and welding processes as well as the control problem associated with manipulated robotic arms in a manufacturing context.

Prerequisite: ME 572 or consent of the instructor

ME 675 Phase Transformations in Metals (3-0-3)

Thermodynamics and phase diagrams. Diffusion. Interface-controlled transformations. Solidification. Diffusion-controlled transformations in solids: precipitate nucleation and growth, TTT diagrams, precipitation hardening, eutectoid transformations, and continuous cooling diagrams. Martensitic transformations.

Prerequisite: Graduate standing

ME 691 Special Topics in Thermofluid Sciences II (3-0-3)

Advanced topics are selected from thermofluid area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering this course.

Prerequisite: Graduate standing

ME 695 Special Topics in Engineering Mechanics II (3-0-3)

Advanced topics are selected from the broad area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering this course.

Prerequisite: Graduate standing

ME 697 Special Topics in Materials and Manufacturing II (3-0-3)
Advanced topics are selected from the broad area of mechanical engineering. Contents of the course will be provided in detail one semester before its offering. Approval of the Departmental Graduate Committee and the Graduate Council must be secured before offering this course.
Prerequisite: Graduate standing

ME 699 Ph.D. Seminar (1-0-0)
Ph.D. students are required to attend Departmental seminars delivered by faculty, visiting scholars and graduate students. Additionally, each Ph.D. student should present at least one seminar on a timely research topic. Ph.D. students should pass the comprehensive examination as part of this course. This course is a co-requisite to registering the Ph.D. Pre-dissertation ME 711. The course is graded as pass or fail. IC grade is awarded if the Ph.D. Comprehensive exam is not yet passed.
Prerequisite: Graduate standing

ME 701 Directed Research I (3-0-3)
This course is intended to allow the student to conduct research in advanced problems in his Ph.D. Research Area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course.
Prerequisite: Prior arrangement with an instructor

ME 702 Directed Research II (3-0-3)
This course is intended to allow the student to conduct research in advanced problems in his Ph.D. Research Area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course.
Prerequisite: ME 701 and prior arrangement with an instructor

ME 711 Ph.D. Pre-Dissertation (0-0-3)
This course enables the student to submit his Ph.D. Dissertation Proposal and defend it in public. The student passes the course if the Ph.D. Dissertation committee accepts the submitted dissertation proposal report and upon successfully passing the Dissertation proposal public defense. The course grade can be NP, NF or IP.
Prerequisite: Ph.D. candidacy
Co-requisite: ME 699

ME 712 Ph.D. Dissertation (0-0-9)
This course enables the student to work on his Ph.D. Dissertation as per the submitted dissertation proposal, submits its final report and defend it in public. The student passes the course if the Ph.D. Dissertation committee accepts the submitted final dissertation report and

upon successfully passing the Dissertation public defense. The course grade can be NP, NF or IP.

Prerequisite: ME 711