

DREXEL UNIVERSITY

Graduate Program Manual

**Approved
May 2010**

This document describes the rules and regulations of the graduate programs in the Department of Mechanical Engineering and Mechanics. Every graduate student of the Department must comply with these rules and regulations in conjunction with University regulations.

To assist the students during their tenure in the Department, and to aid them adhere to the rules and regulations, the following faculty members will serve as their Advisors unless arranged otherwise.

Area/Program	Advisor	Telephone No.	Bldg./Room
Mechanics Area	Dr. T. M. Tan	(215) 895-2293	3-155C
Systems & Control Area	Dr. B. C. Chang	(215) 895-1790	4-172C
Thermal & Fluid Sciences Area	Dr. Young Cho	(215) 895-2425	3-157
Design & Manufacturing Area	Dr. Jack Zhou	(215) 895-1480	4-172E

Welcome aboard. We wish you the best in your graduate studies.

[Dr. Alan Lau](#)
Graduate Advisor
(215) 895-2377

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I. GENERAL INFORMATION

The rules and regulations described herein pertain to the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) programs in the Department of Mechanical Engineering and Mechanics (MEM) as of the Spring Quarter 2010. All students entering either the M.S. program or the Ph.D. program must follow the rules and regulations set forth herein. Students are reminded that in addition to these departmental rules, they have to meet Drexel University graduate requirements as described by [Office of Graduate Studies](#).

1.1 Core Areas and Subject Areas

The MEM Department offers the following four **core** areas for specialization: Mechanics, Thermal & Fluid Sciences, Systems & Control, and Design & Manufacturing.

CORE AREA	SUBJECT AREAS	CORE COURSE SEQUENCES
Mechanics	Theory of Elasticity	MEM 660, MEM 661
	Solid Mechanics	Any two from MEM 663, MEM 777, MEM 664, MEM 665
	Advanced Dynamics	MEM 666, MEM 667
Thermal & Fluid Sciences	Advanced Thermodynamics	MEM 601, MEM 602
	Heat Transfer	Any two from MEM 611, MEM 612, MEM 613
	Fluid Mechanics	MEM 621, MEM 622
Systems & Control	Robust Control Systems	MEM 633, MEM 634
	Non-linear Control Theory	MEM 636, MEM 637
	Real Time Microcomputer Control	MEM 639, MEM 640
Design & Manufacturing	Manufacturing	Any two from MEM 687, MEM 688, MEM 617

To provide sufficient mathematical foundation required for these courses, the MEM Department offers a three-quarter sequence in applied mathematics entitled "Engineering Analysis" (MEM 800/591, 800/592, 800/593 for on-campus; MEM 800/X01, 800/X02, 800/X03 for off-campus). This sequence is equivalent to the sequence "Advanced Engineering Mathematics" (MCS 544, 545, 546) offered by the Mathematics and Computer Science Department.

1.2 Plan of Study

All students entering the MEM Department must file an approved M.S. or Ph.D. Plan of Study. With the consultation of the student's Advisor, the Plan of Study must be filed prior to the third term of study since the requirements for graduation will be those in effect at the time of filing. Any changes or deviations from this Plan of Study that may affect the fulfillment of degree requirements must be approved in writing, in advance, by filing a new Plan of Study. ***Failure to file a Plan of Study or failure to obtain prior written approval to any changes in a Plan of Study may result in non-acceptance of the un-approved courses for fulfilling the degree requirements.***

II. REQUIREMENTS FOR THE M.S. DEGREE

2.1 M.S. Degree Requirements

2.1.1 M.S. Thesis

The M.S. Thesis is optional. If the Thesis Option is chosen, the student should register for MEM898 Master's Thesis credits. The work for an M.S. Thesis will generally be completed under the supervision of a faculty advisor who will direct the research work, assign grades for the Thesis credit, and review the final Thesis document. The Thesis must be approved by the faculty advisor before the student can be cleared for graduation. See Section 2.2.2 for further details.

2.1.2 M.S. Courses

The minimum course requirement for the M.S. Degree is 45 credits, including credits of the optional M.S. Thesis. Students may transfer not more than 15 credits (equivalent to 10 semester-credits) from approved institutions, provided they follow the rules and regulations described in the Drexel University's Graduate Curricula. These 45 credits consist of the required 9 credits of applied mathematics, the required 12 credits of core area courses, and the remaining 24 credits of technical elective courses, as tabulated below.

Mathematics courses (required)	9 Credits
Core Area courses (required)	12 Credits
Technical elective courses	24 Credits
TOTAL	45 Credits

The 9 credits of applied mathematics may be fulfilled by taking either the applied mathematics course sequences mentioned in Section I, or any other approved equivalent mathematical courses. The 12 credits of core area courses may be fulfilled by taking any two core course sequences, each from a different core area, as listed in Section I.

Of the remaining 24 technical elective credits, at least 12 must be taken from within the MEM Department, while the rest may be taken from the College of Engineering, College of Arts and Sciences, or from other colleges, if consistent with the student's Plan of Study and given advance written approval by his/her Advisor. Out of the 24 technical elective credits, a Thesis-Option student may complete up to 18 credits for MEM898 Master's Thesis and MEM699 Independent Study and Research. Out of the 24 technical elective credits, a Non-Thesis Option student may complete up to 9 credits for MEM699 Independent Study and Research.

2.2 M.S. Procedural Requirements

2.2.1 M.S. Plan of Study

Upon approval by their Advisors, students in the M.S. Program must file a Plan of Study, MEM GR-1 Form (attached) with the Graduate Advisor prior to the third quarter of study. This Plan of Study should clearly indicate how the course requirements cited above are satisfied, whether or not the M.S. Thesis option is chosen, and must also indicate any applicable transfer of credits. Students holding a Bachelor's degree in a Science Department or Engineering Department other than Mechanical Engineering are typically advised to take several undergraduate courses as preparation for graduate studies in MEM Department. Though these courses are not counted toward the required 45 credits for M.S. Degree (or 48 credits for POMEPE students), they also must be listed in the Plan of Study.

2.2.2 Clearance of M.S. Candidate for Graduation

At the beginning of the expected quarter of graduation, the M.S. candidate will file the completed MEM GR-2 Form "Clearance for M.S. Degree Applicant" (attached) with the Graduate Advisor. If the M.S. Thesis option has been pursued then the MEM GR-2A Form "Clearance for M.S. Thesis" (attached) must also be filed. When this Form(s) shows that all departmental requirements have been satisfied, the Graduate Advisor will clear the student for graduation.

III. REQUIREMENTS FOR THE Ph.D. DEGREE

A student admitted into the Ph.D. Program is classified as a Ph.D. Applicant. After the successful completion of the Ph.D. Candidacy Examination (described below), the classification of the student changes to Ph.D. Candidate. Each Ph.D. Applicant must obtain, from the Office of Graduate Studies, the Ph.D. Forms Booklet. This booklet contains forms for filing Plan of Study, appointment and approval of supervising professor, appointment of various examination committees, and reporting of the results of these examinations. The rules, regulations, and procedures pertaining to the required credits and the governance of the Ph.D. Candidacy Examinations are described below.

3.1 Ph.D. Degree Requirements

The Ph.D. degree requirements include 5 major elements:

- Course Requirements
- Candidacy Examination
- Thesis Committee and Meetings
- Thesis Proposal
- Thesis Completion and Defense

3.1.1 Ph.D. Course Requirements

By graduation, Ph.D. students must have completed:

(a) For students entering the Ph.D. program with a M.Sc. degree – 45 credits of graduate courses out of which 18 credits are graduate courses exclusive of Independent Study and Dissertation. If the M.Sc. degree was not from the MEM department, 12 of these 18 credits must be MEM graduate courses (600-level or above).

(b) For students entering the Ph.D. program with a B.Sc. degree (i.e. without a M.Sc. degree) – 90 credits of graduate courses. 45 of these 90 credits must satisfy the MSME degree requirements. The remaining 45 credits must satisfy the requirement in (a) above.

3.1.2 Ph.D. Candidacy Examination

Every Ph.D. Applicant is required to take the Ph.D. Candidacy Examination.

3.1.2.1 Eligibility

A graduate student in the Ph.D. program with good academic standing must be nominated by his/her supervising advisor to take the candidacy examination.

3.1.2.2. Examination Committee

- a. The Candidacy Examination Committee can be formed as soon as the student enters the PhD program, but no later than four weeks before the student takes the candidacy examination.
- b. With the consent of the student, the supervising advisor forms the Candidacy Examination Committee for the student. The supervising advisor may serve in this committee but cannot serve as chair of this committee.
- c. Membership of the Committee is as stipulated in the Graduate Studies Office D3 Form: The Committee must consist of at least five members, at least three of whom must be currently tenured or tenure-track Drexel faculty members. At least two of the committee members must be from outside the student's major area. At least one of the committee members must be from outside the student's department.
- d. During the transition period of 12 calendar months from the start of implementation of the new rule (i.e. starting from May 1st 2010), the following transitional mechanism is activated: Unless otherwise approved by the Graduate Advisor, one member of the candidacy exam committee will need be a member of the Graduate Curriculum Committee – in order to ensure consistency and provide feedback to the Graduate Curriculum Committee on the way the candidacy exams are administered. At the discretion of the Graduate Curriculum Committee, the Graduate Advisor can deputize an experienced non-committee faculty member to perform this service on behalf of the Graduate Curriculum Committee.
The above transitional mechanism will sunset (cease to apply) after 12 calendar months.

3.1.2.3. Structure of the Candidacy Examination

The Candidacy Examination consists of two components: 1) a “course component” and 2) a “research component”. The student must demonstrate excellence in both components.

3.1.2.3.1. Course Component

At the discretion of the supervising advisor, and with the approval of the MEM Graduate Advisor, the course-component for attaining Candidacy can be satisfied by either one of the following two mechanisms

Excellent performance (a grade of A) in any two core courses from MEM core areas

Excellent performance in a written examination prepared by the Candidacy Examination Committee. The content covered in this examination is decided by the Committee.

3.1.2.3.2 Research Component

The research-component of attaining Candidacy is satisfied by a written report and an oral presentation of a review. The Committee selects three or more papers in student's declared research area for student to conduct a critical review. In three weeks the student submits a written report (less than 10 pages) and makes an oral presentation within one week after the written report has been submitted. The presentation (less than 40 minutes) is followed by questions by the Committee. The goals of the questions: To evaluate the student's knowledge in the scientific fields related to the research area, including related background and fundamental material, and the student's ability to integrate information germane to success in research.

3.1.2.4. Timing

Post-BS PhD student (i.e. student who enters the Ph.D. program without a prior M.Sc. degree): Must take the Candidacy Examination within 2 years after entry to the PhD program. Post-MS PhD student (i.e. student who enters the Ph.D. program with a prior M.Sc. degree): Must take the Candidacy Examination within the first year after entry to the PhD program. This timing is consistent with the Graduate Studies Office requirement on accumulated credits to attain Ph.D. Candidate status, and with the Graduate Studies Office requirement that all programs must allow their doctoral students to attain Doctoral Candidate Status within the first 2 years of the program.

3.1.2.4. Repeat examination

At the discretion of the Candidacy Examination Committee, a student who does not pass the course-component and/or the research component of the Candidacy examinations may retake the respective component examination once.

3.1.2.5. Release from Ph.D. Program

Release from the Ph.D. Program will be consistent with Drexel policy. A student who does not attain Candidacy status within two years after first entry into the Ph.D. program, will be released from the Ph. D. program,

3.1.3. Thesis Advisory Committee and Committee Meetings

Upon successful completion of the Ph.D. Candidacy Examination, the student's Supervising Professor will form a Thesis Advisory Committee for the student. This committee is chaired by the Supervising Professor. Its membership is governed by the stipulation in Form D-5 "Ph.D. Thesis Advisory Committee" of the Office of Graduate Studies. The Thesis Advisory Committee is required to meet at least once every twelve months.

3.1.4. Thesis Proposal

The Ph.D. Candidate is required to give a presentation of his/her Dissertation topic to his/her Thesis Advisory Committee. This presentation should be publicly announced and open to the public. The student will submit a comprehensive Ph.D. Dissertation Proposal, which normally will include but not limited to abstract, introduction, detailed literature review, research progress, proposed research, and timetable. The committee will approve/reject the general methodology and approach and the scope of work so that it can be completed in a manageable time. The result of the presentation will be reported to the Graduate Advisor on MEM GR-4 Form "Approval of the Ph.D. Dissertation Topic" (see Section V below).

3.1.5 Foreign Students with M.S. Degree from Foreign Institutions

Students under this category may be required to take a special course in an "English as a Second Language" Program before entering Drexel University. Information on this course is provided upon application to the Graduate Program at Drexel University. Once admitted to Drexel University, in order to be appointed as Teaching Assistants, students must enter into Drexel's Incoming Foreign Teaching Assistant Program. The program is recommended for all incoming foreign students for improving their proficiency in the English language and for exposing them to the teaching techniques and campus life at Drexel University.

3.1.6 Other Requirements

All Ph.D. Candidates are expected to teach and participate in other educational activities of the MEM Department, such as the departmental Seminar Series.

3.2 Ph.D. Procedural Requirements

3.2.1 The D Forms

The sequential D-Forms of the [Office of Graduate Studies Office](#) guide the student step-by-step through the procedural requirements of the Ph.D. process.

[Form D-1: Plan of Study](#)

Upon approval by their Advisors, students in the Ph.D. Program must file a Form D-1 "Ph.D. Plan of Study" with the Office of Graduate Studies through the Graduate Advisor as soon as possible but prior to the third quarter of study. This Plan of Study should clearly indicate how the course requirements cited above are satisfied, and list all required examinations, such as Ph.D. Candidacy Examination, along with the dates taken or expected to be taken.

[Form D-2: Appointment of a Supervising Professor](#)

A supervising professor should be appointed using the [Form D-2](#) by the end of a doctoral student's second year of study.

Form D-3: Doctoral Candidacy Committee Appointment & Exam Schedule

The [Form D-3](#) must be filed with the Office of Graduate Studies at least four (4) weeks prior to the scheduled date of the examination. This form specifies the required composition of the Doctoral Candidacy Committee and documents the committee members. Please follow specific committee composition requirements on the form.

Forms D-4 and D-4a: Reports on Candidacy Examination

Students should bring [Form D-4](#) and copies of [Form D-4a](#) for each committee member to their examination.

Form D-5: Appointment of the Thesis Advisory Committee

The [Form D-5](#) should be filed prior to the proposal defense. This form specifies the required composition of the Thesis Advisory Committee and documents the committee members. Please follow specific committee composition requirements on the form.

Form D-6: Appointment of the Final Oral Defense Committee

This form is used to schedule the final defense of the dissertation. It is to be filed with the Office of Graduate Studies at least four (4) weeks prior to the final defense date.

Form D-7: Report of the Final Oral Defense Committee

This form must be filed with the Office of Graduate Studies within 48 hours after the completion of the final oral examination. This form documents the results of the final dissertation oral defense. Students should bring [Form D-7](#) to their examination.

3.2.2 Clearance of Ph.D. Candidate for Graduation

The Ph.D. Candidate will be cleared for graduation by the Graduate Advisor after filling out the MEM GR-5 Form "Clearance for Ph.D. Degree Applicant" (see Section V below) to ascertain that all departmental requirements have been satisfied. This form must be filed 30 days prior to and not later than 10 days before the end of the quarter in which the student is expected to complete the requirements.

Finally, following the approval of MEM GR-5 Form, the Ph.D. Candidate must complete the [Completion Form](#) with the Office of Graduate Studies. Submission of the Dissertation with the Drexel University Library is a prerequisite for completing this form. The Completion Form should be filed as soon as possible but no later than the first day of final examination week of the term in which they plan to graduate.

IV. TOPICAL COVERAGE IN SUBJECT AREAS

4.1 Fundamental Material

The material listed in this Section (Section 4.1) is undergraduate material that helps to build the foundation for graduate-level core courses described in Section 4.2 below. In the Preliminary Examination, students are examined on material from two graduate-level core course sequences (Section 4.2).

4.1.1 Mechanics Area

Major Topics

Statics (MEM202): Concurrent force systems; statics of particles; equivalent force/moment systems; distributed forces; centroids; equilibrium of rigid bodies; trusses, frames and machines; internal forces in structural members; friction; moments of inertia.

Dynamics (MEM238): Kinematics of particles (Newton's Second Law, energy and momentum methods); kinematics of rigid bodies; plane motion of rigid bodies.

Mechanics Of Materials (MEM230, MEM330): Tension, compression and shear; axially loaded members; torsion; shear forces and bending moments; stress in beams; analysis of stress and strain; deflections of beams; statically indeterminate beams; columns; energy principles. Further Information: By request from [Dr. T. Tan](#)

4.1.2 Thermal Fluid Sciences Area

Major Topics

Fluid Mechanics (MEM220, MEM320): Fluid statics, conservation equations for fluid motion, applications of the Bernoulli equation, pipe flow, basic inviscid and potential flow, basic compressible flow, one-dimensional isentropic, normal shock, two-dimensional supersonic flow, oblique shocks and Prandtl-Meyer expansion, supersonic nozzles, diffusers

Heat Transfer (MEM345, MEM440): Fundamentals of heat transfer by conduction, convection, and radiation; steady and unsteady heat conduction, forced and free convection. Combined heat transfer problems in engineering systems.

Thermodynamics (MEM310, MEM410): Fluid properties, First and Second Law applications, thermal efficiencies, properties of real fluids, analysis of ideal and real gas mixtures; gas-phase reacting systems.

Further Information: By request from [Dr. Y. Cho](#)

4.1.3 Systems and Control Area

Major Topics

Introduction to Control (MEM255): Modeling of linear & nonlinear systems, linearization, transfer functions, poles and zeros, state-space models, eigenvalues, eigenvectors and transition matrices, block diagrams and signal flow graphs, frequency and time-domain analysis.

Control System Design (MEM355): Root-locus and Nyquist techniques, Compensator design, Stability, controllability, and observability, regulator, observer, and set-point controllers.

Microcomputer Based Control Systems (MEM458, MEM459): Discrete-time systems, z-transform, sampling theorem, the pulse transfer function, discrete state equations, stability, time-domain analysis, frequency-domain analysis, design of discrete-time controllers, digital simulation, microcomputer and microprocessor implementation of digital controllers.

Further Information: By request from [Dr. B.C. Chang](#).

4.2 Core Course Sequences

The Preliminary Examination covers material from two of the nine core course sequences listed in Section I. The material covered in each of the core course sequence include but not limited to those topics listed below.

4.2.1 Theory of Elasticity

Major Topics

Review of Mechanics of Materials; vector and tensor analysis; indexical notation; integral theorem; analysis of stress; equilibrium equations; principal stresses and stress invariants; analysis of strain; displacements and small strains; principal strains and strain invariants; compatibility; generalized Hooke's law; engineering elastic constants; governing equations in linear elasticity; strain energy; uniqueness of solution; Saint-Venant's principle; elementary problems in three dimensions.

Two dimensional problems in Cartesian and polar coordinates; solution by polynomials and Fourier series; Airy's stress function; solution by means of complex variables; torsion problem; bending of bars.

Three-dimensional problems, elastic contact; energy principles and applications; Rayleigh-Ritz methods; advanced topics.

Reference Material

Timoshenko, S.P. and Goodier, J.M., Theory of Elasticity, McGraw-Hill, 3rd ed., 1970.

Chou, P.C. and Pagano, N.J., Elasticity, Dover, 1992.

Recommended Courses

Theory of Elasticity I & II (MEM 660, MEM 661)

Further Information: By request from [Dr. T. Tan](#)

4.2.2 Solid Mechanics

Major Topics

The student is expected to have knowledge on the foundations of continuum mechanics. Major subjects include: Algebra and analysis of tensors. Kinematics of deformable bodies: material and spatial descriptions; material time derivative; measures of strain; rate of deformation and spin tensors. Balance principles: conservation of mass, linear and angular momentum, balance of energy; Cauchy and Piola-Kirchhoff stress tensors.

Constitutive equations: Introduction to phenomenological plasticity; strain-stress curves; ideal plastic models; crystal plasticity; fundamental one-dimensional problems; stress and strain deviatoric tensors; Von Mises and Tresca yield criteria; flow laws; isotropic and kinematic strain hardening. Nonlinear behavior of materials; kinematics of large deformations; Cauchy and Green elasticity; exact solutions for compressible and incompressible nonlinear elastic materials.

Reference Material

Chandrasekharaiah, D.S. and Debnath, L., Continuum Mechanics, Academic Press, 1994.

Fung, Y.C., Foundations of Solid Mechanics, Prentice Hall, 1965.

Gurtin, M., An Introduction to Continuum Mechanics, Academic Press, 1981.

Lubliner, J., Plasticity Theory, Mac Millan, 1990.

Malvern, L.E., Introduction to the Mechanics of a Continuous Medium, Prentice- Hall, 1969.

Recommended Courses

Continuum Mechanics (MEM 663)

Introduction to Plasticity (MEM 664)

Time- Dependent Solid Mechanics (MEM 665)

Further Information: By request from [Dr. H. Sosa](#).

4.2.3 Advanced Dynamics

Major Topics

The student will be expected to show competence in Analytical Dynamics (Lagrangian) as well as Vector Dynamics in three dimensions (Eulerian). As a prerequisite, the student must have an undergraduate background in Statics and Dynamics at the level of the text by Beer & Johnston, as well as working knowledge of Vector Analysis and Matrix Algebra.

The topical coverage the student should be conversant with includes, but is not limited to: analytical statics, principle of virtual work, Lagrange's equations, generalized coordinates and forces, stability about dynamic equilibrium, conservation of generalized momentum constraints, Lagrange multipliers, generalized impulse and momentum, nonholonomic constraints, central forces, effect of rotation of the earth, three-dimensional vector dynamics applied to systems of particles and rigid bodies, linear vibration theory for systems with multiple degrees of freedom, normal coordinates, small oscillations about steady state.

Reference Material

Beer, F.P. and Johnston, E.R., Vector Mechanics for Engineers, 3rd ed., McGraw-Hill, 1977 (Elementary level).

Greenwood, D.T., Classical Dynamics, Prentice Hall, Inc., 1977 (Advanced level).

Recommended Courses

Advanced Dynamics I & II (MEM 666, MEM 667).

Further Information: By request from [Dr. S. Siegler](#).

4.2.4 Advanced Thermodynamics

Major Topics

The student will be tested for competence in classical and statistical thermodynamics. The student is also expected to be able to demonstrate a reasonable background in undergraduate thermodynamics topics at the level of the texts by Van Wylen and Sonntag, Wark, or Black and Hartley.

The topical coverage includes, but is not limited to: first and second laws and properties of real and ideal substances, basic kinetic theory of gases, velocity and speed distributions, transport properties, elementary quantum mechanics, including energy level and degeneracy concepts, classical and quantum statistics, calculation of thermodynamic properties of ideal gases and gas mixtures, chemical equilibrium and thermochemistry, and real gas equations of state.

Reference Material

Wark, Thermodynamics, 5th ed., McGraw-Hill, 1988.

Van Wylen and Sonntag, Fundamentals of Classical Thermodynamics, 3rd ed., Wiley, 1986.

Callen, Thermodynamics and an Introduction to Thermostatistics, 2nd ed., Wiley, 1985.

Incorpera, Introduction to Molecular Structure & Thermodynamics, Wiley, 1984.

Tien and Lienhard, Statistical Thermodynamics, Hemisphere, 1979.

Smith, Elementary Statistical Thermodynamics, Plenum, 1982.

Herzberg, Spectra of Diatomic Molecules, Van Nostrand & Reinhold, 2nd ed., 1950.

Sonntag and Van Wylen, Fundamentals of Statistical Thermodynamics, Krieger, 1985.

Bejan, Advanced Engineering Thermodynamics, Wiley, Interscience, 1988.

Lay, Statistical Mechanics and Thermodynamics of Matter: An Introductory Survey, Harper & Row, 1990.

Black and Hartley, Thermodynamics, Harper Collins, 1991.

Recommended Courses

Statistical Thermodynamics I & II (MEM 601, MEM 602).

Further Information: By request from Drs. [N. Cernansky](#) and [D. Miller](#).

4.2.5 Heat Transfer

Major Topics

Basic concepts in heat transfer and fundamental mechanisms, the heat conduction equation and its boundary conditions, analytical solutions of steady state and transient heat conduction equation with and without heat generation, application of transform techniques, heat conduction with moving boundaries.

Heat transfer in free and forced convection, the equations of motion and energy, boundary layer analysis, determination of friction factor and heat transfer coefficients, fundamentals of boiling and condensation, basic thermal analysis of heat exchangers.

The concept of blackbody radiation, radiation heat transfer among surfaces separated by a nonparticipating medium, problems involving radiation combined with conduction and convection.

Reference Material

Eckert and Drake, Analysis of Heat and Mass Transfer, McGraw-Hill.

Arpaci, Conduction Heat Transfer, Addison-Wesley, 1966.

Kays and Crawford, Convective Heat and Mass Transfer, McGraw-Hill, 1993.

Siegel and Howell, Thermal Radiation Heat Transfer, McGraw-Hill, 1993.

Incorpera and Dewitt, Fundamentals of Heat and Mass Transfer, Wiley, 3rd ed., 1990.

Kakac and Yener, Heat Conduction, Hemisphere Publishing Co., 1985.

Bejan, Convection Heat Transfer, Wiley, 2nd edition, 1995.

In addition, it is recommended that the student be familiar with the materials covered in a typical undergraduate heat transfer text.

Recommended Courses

Conduction Heat Transfer (MEM 611).

Convection Heat Transfer (MEM 612).

Radiation Heat Transfer (MEM 613).

Further Information: By request from Drs. [B. Farouk](#) and [Y. Cho](#).

4.2.6 Fluid Mechanics

Major Topics

The student is expected to have a basic understanding of the principles of fluid mechanics and the methods for the analysis of 2-D ideal and viscous fluids. It is assumed that the student has the analytical background in vector and tensor analysis, complex variables and differential equations.

The topical coverage may include, but is not limited to: concept of fluid as a continuum, kinematics, conservation laws for fluids, vorticity and circulation, ideal inviscid 2-D flows, momentum integral equations, Navier-Stokes equations, exact solutions of the Navier-Stokes equations, viscous flows, laminar boundary layers including non-steady flows, similarity methods, asymptotic methods, introduction to stability, turbulence, shock waves, and compressible flows.

Reference Material

Schlichting, H., Boundary Layer Theory, 7th Ed., McGraw-Hill, 1979.
Currie, I.G., Fundamental Mechanics of Fluids, McGraw-Hill, 1974.
White, F., Fluid Mechanics, McGraw-Hill, 1986.
White, F., Viscous Fluid Flow, McGraw-Hill, 2nd Ed., 1991.
Batchelor, G. K., An Introduction to Fluid Dynamics, Cambridge University Press, 1973.

Recommended Courses

Foundation of Fluid Mechanics (MEM 621)
Boundary Layer Theory (MEM 622)
Further Information: By request from [Dr. D. Wootton](#).

4.2.7 Robust Control Systems

Major Topics

Linear spaces and linear operators; internal stability, coprime factorization, matrix fraction description, irreducible MFD's, Smith-McMillan form; poles and zeros; canonical realizations of multivariable systems, minimal realizations; structure of stabilizing controllers; algebraic Riccati equation, state-space computation of coprime factorizations; YJB controller parametrization; linear fractional transformation; state-space structure of the proper stabilizing controllers; formulation of control problems; optimization problem, optimization problem, model matching problem, tracking problem, robust stabilization problem; inner-outer factorizations, spectral factorizations; Sarason's interpolation theory; Hankel-norm approximations, balanced realizations.

Reference Material

Francis, B. A., A Course in Control Theory, Springer-Verlag, 1987.
Vidyasagar, M., Control System Synthesis - A Factorization Approach, The MIT Press, 1985.
Chen, C-T, Linear Systems Theory and Design, CBS College Publishing, HRW, 1984.
Kailath, T., Linear Systems, Prentice-Hall, Inc., 1980.
Kwakernaak, H., and Sivan, R., Linear Optimal Control Systems, John Wiley & Sons, Inc., 1972.
Zhou, K., Doyle, J. C. and Glover, K., Robust and Optimal Control, Prentice Hall, 1996.

Recommended Courses

Robust Control Systems I & II (MEM 633, MEM 634)
Further Information: By request from [Dr. A. Yousuff](#).

4.2.8 Nonlinear Control Theory

Major Topics

The student will be expected to demonstrate a broad knowledge in the qualitative behavior of nonlinear dynamical systems as well a facility in methods of nonlinear systems analysis and control system design. As a prerequisite to study in this field, the student should have a solid background in linear systems analysis and control systems design and background first year graduate mathematics including linear algebra and ordinary differential equations. The student should also be comfortable with the use of the computer in engineering analysis.

The topical coverage will include, but is not limited to: geometric theory of nonlinear dynamics; stability, controllability and observability of nonlinear systems; exact linearization, decoupling and stabilization by smooth feedback; systems with parameters: bifurcation and stability; regulator design; tracking and regulation; discontinuous feedback control.

Reference Material

Isidori, A., Nonlinear Control Systems: An Introduction, Springer-Verlag, 1989.

Beltrami, E., Mathematics for Dynamic Modeling, Academic Press, 1987.

Gelb, A. and Vander Velde, W. E., Multiple-Input Describing Functions and Nonlinear System Design, McGraw-Hill: New York, 1968.

Guckenheimer, J. and Holmes, P., Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields, Springer-Verlag: New York, 1983.

Hagedorn, P., Non-Linear Oscillations, Oxford University Press: New York, 1981.

La Salle, J. and Lefschetz, S., Stability by Liapunov's Direct Method, Academic Press, New York, 1961.

Utkin, V. I., Sliding Modes and Their Application in Variable Structure Systems, MIR: Moscow, 1978.

Recommended Courses

Nonlinear Control Theory I & II (MEM 636, MEM 637)

Further Information: By request from [Dr. H.G. Kwatny](#).

4.2.9 Real Time Microcomputer Control

Major Topics

Discrete-time systems and the z-transform; sampling and data reconstruction; the pulse transfer function; discrete state equations; time-domain analysis; digital simulation; stability; frequency-domain analysis; introduction to LabVIEW programming; data acquisition and processing.

Design of discrete-time controllers; sampled-data transformation of analog filter; digital filters; microcomputer implementation of digital filters; LabVIEW programming techniques; using the DAQ library; writing a data acquisition program; LabVIEW implementation of PID controllers.

Reference Material

Phillips, C. L. and Nagle, H. T., Digital Control System Analysis and Design, 3rd Edition, Prentice-Hall, 1995.

National Instruments, LabVIEW Student Edition, Prentice-Hall, 1995.

The MATH Works Inc., The Student Edition of MATLAB for Macintosh Computers, Version 4, Prentice Hall, 1995. (1992 Edition is also acceptable.)

Johnson, G.W., LabVIEW Graphical Programming: Practical Applications in Instrumentation and Control, McGraw-Hill, 1994.

Franklin, G. F., Powell, J. D., and Workman, M. L., Digital Control of Dynamic Systems, Addison-Wesley, 1990.

Astrom, K. J., Wittenmark, B., Computer Control Systems, Prentice-Hall, 1984.

Recommended Courses

Real Time Microcomputer Control I & II (MEM 639, MEM 640)

Further Information: By request from [Dr. B.C. Chang](#).

V. FORMS REQUIRED FOR M.S. AND PH.D.

5.1 FORMS REQUIRED FOR MASTER OF SCIENCE (M.S.)

FORM	PURPOSE	SUBMIT TO	WHEN
GR-1	Plan of Study (.pdf)	Graduate Advisor	Before the 3rd term of studies
GR-2	Clearance (.pdf)	Graduate Advisor	Term of graduation
GR-2A	Clearance for Thesis (1) (.pdf)	Graduate Advisor	Term of graduation

5.2 FORMS REQUIRED FOR DOCTOR OF PHILOSOPHY (Ph.D.)

FORMS	PURPOSE	SUBMIT TO	WHEN
	Re-admission Form ^{en} (.pdf)	Grad Adv. & OGS	(2)
D-1	Plan of study	Grad Adv. & OGS	Before the 3rd term of studies
D-2	Supervising Professor Appointment	Grad Adv. & OGS	Before the candidacy examination
GR-3	Preliminary Examination Request (.pdf)	Grad Adv.	One term before the examination
GR-4	Candidacy Examination Request (.pdf)	Grad Adv.	One term before the examination
D-3	Candidacy Committee	Grad Adv. & OGS	After passing written examination
D-4	Report of Candidacy Committee	Grad Adv. & OGS	Within 48 hours of the oral examination
D-4a	Individual Reports	OGS	Along with form D-4
D-5	Thesis Advisory Committee	Grad Adv. & OGS	After passing the candidacy examination
GR-5	Approval of Thesis Topic (.pdf)	Grad Adv.	After approval of proposal
D-6	Final Oral Examination Committee	Grad Adv. & OGS	4 weeks before final oral examination
D-7	Report of Final Oral Examination	Grad Adv. & OGS	Within 48 hours of the examination
GR-6	Clearance (.pdf)	Grad Adv.	During term of graduation
	Completion Form ^{en} (.pdf)	OGS	Before commencement

Notes: D-forms are in the [Ph.D. FORMS Website](#) [☞], available from the Office of Graduate Studies (OGS).

Grad Adv. & OGS means that the form needs signatures from both parties.

Ph.D. students are encouraged to follow instructions available from the [Office of Graduate Studies Website](#) [☞] regarding graduation and thesis requirements.

(1) For students taking Thesis option.

(2) This form is used by Drexel M.S. students to apply for enrolling into the Ph.D. Programs.