

# Preliminary Examination Guidelines

## Purpose:

The Preliminary Exam establishes whether the Ph.D. Candidate understands sufficiently well some important fundamental material in the fields of mechanical engineering and aerospace engineering; he/ she must show the ability to synthesize different elements of knowledge to solve open-ended problems; and a capability for sound scientific scrutiny and judgment must be observed. The exam cannot be taken before the student has clearly established a mutual agreement with a research advisor for their doctoral work. Proficiency in oral English must be demonstrated before registration for the exam.

## Format:

The Preliminary Exam has three parts (A), (B), and (C), will be offered during the Preliminary Exam week. The first portion is a written exam whereas the other two are oral examinations. Each student is required to take all three parts. The student must choose one of four available Major areas: Dynamics and Control, Fluid Mechanics, Solid Mechanics, or Thermal Science and Transport.

(A) Applied Mathematics. 90-minute written examination.

(B) Dynamics and Control, or  
Fluid Mechanics, or  
Solid Mechanics, or  
Thermal Science and Transport. 60--90-minute oral examination in the Major area.

At the start of the discussion of each new exam question, that question will be presented in writing to the student.

(C) Synthesis and Integration. 60-minute presentation and oral examination.

## Registration:

The student together with the research advisor must petition for the Preliminary Exam at least six weeks prior to the start of the Exam period. Students should meet the requirements for "Demonstration of Oral English Proficiency for Teaching Assistant Employment" as described in the UCI catalogue before petitioning for the Preliminary Exam. Petition forms are available at [http://mae.eng.uci.edu/grad/preli\\_exam\\_form.pdf](http://mae.eng.uci.edu/grad/preli_exam_form.pdf)

## Leaders:

The Graduate Studies Committee chooses examiners, including exam chairs, for the five topical portions of the Parts A and B of the exam. The examiners for the 2008-2009 and 2009-2010 years are indicated below using initials:

**Part A**

Applied Math – FL (Chair), DD, AS, BV

**Part B**

Dynamics & Controls – KDM (Chair), JEB, FJ, JMM, DJR, AMS

Fluid Mechanics – SEE (Chair), HC, JCL, DP, WAS

Solid Mechanics – SNA, LV, Farghalli Mohamed, and Lizhi Sun

Transport / Thermo – DDR (Chair), MGC, MM, RHR, GSS, YW

**Part C**

Variable leadership. See document related to System and Integration for details. These teams shall take responsibility for formulating and conducting their corresponding parts of exam for the two years, 2008-2009 and 2009-2010.

**Schedule:**

The dates for the two annual offerings of the Preliminary Exam are:

- Fall Quarter: the week immediately prior to Thanksgiving week, November 16-20, 2009.
- Spring Quarter: the third week of Spring Quarter, April 12-16, 2010.

Graduate students admitted to the M.S./Ph.D. program shall normally take the Preliminary Exam for the first time during the Fall Quarter of their second year in the program. Students who join the Department with a M.S. degree must take the Preliminary Exam (for their first time) by Fall of their second year. Students should take all three parts of the exam during their first attempt. If a second chance is required for the examination, it shall normally be taken during the Spring Quarter of the second year and students have to re-take only the parts of the exam that failed before. Students who do not take the Preliminary Exam in a timely fashion as defined above will not be considered to be in good academic standing and may not be allowed to continue in the Program.

**Grading:**

Each of the Exam portions will receive a separate pass or fail grade from the responsible faculty team. Any portion failed in the first taking must be retaken. If any portion is failed twice, the student has failed the Preliminary Examination and may not continue for the Ph.D. degree. Students must pass all three portions.

At least four faculty members will constitute each exam committee for Parts A and B. Only three Examiners will be present during the Major exam (Part B). The candidate's advisor should not be present during Part A and Part B of the exam. After the week of exams, the group of three examiners for each Major Exam and examiners for the Applied Math Exam will meet and vote on the performance of all students. In order to pass any portion of the Exam, two out of the three examiners must vote for "pass". See document related to System and Integration for details.

## Dynamics and Control Preliminary Exam Topics

### Kinematics and Dynamics (Ref. 1, relevant course MAE 241)

- Particle kinematics and dynamics (Ch. 2, 3)
- Rigid body kinematics and dynamics (Ch. 7, 8)
  - Rotation matrix and parametrizations. SO(3)
  - Angular velocity
  - Inertia matrix
  - Newton-Euler equations
- Holonomic and nonholonomic constraints (Section 6-3)
- Lagrangian dynamics (Ch. 6)

### Dynamical Systems and Control (relevant course MAE 270A, 275, 276)

- Equilibria (Ref. 3, 4, 6)
- State space view of solutions of 2<sup>nd</sup> and 3<sup>rd</sup> order systems (Ref. 4)
- Approximate linearization of nonlinear systems (Ref. 4)
- Stability: definitions; tests (eigenvalues, Lyapunov function) for equilibria (Ref. 3, 4)
- Benefits of feedback control (Ref. 2)
- Linear control design using transfer functions. root locus and Bode plots (Ref. 2)
- Solution of  $\dot{x} = Ax + Bu$  for linear time-invariant (LTI) and time-varying cases (Ref 3)
- Controllability and observability: definitions; tests for LTI system (Ref. 3, 4, 6)
- Minimal state space realization for LTI system (Ref. 3, 6)
- Set point regulation via linear state feedback (Ref. 3, 4, 6)
- Asymptotic tracking via linear state feedback (Ref. 3, 4, 6)

### Optimization (relevant course MAE 206)

- Theory
  - Necessary and sufficient conditions for unconstrained minimization (Ref. 5, Ch. 6)
  - Necessary and sufficient conditions for constrained minimization (Ref. 5, Ch. 10)
- Methods
  - Steepest descent (Ref. 5, Ch. 6)
  - Newton and quasi-Newton (Ref. 5, Ch. 8)

### References:

1. D. T. Greenwood, Principles of Dynamics, 2<sup>nd</sup> ed., Prentice-Hall, 1988.
2. Franklin and Powell. Feedback Control
3. C. T. Chen. Linear System Theory and Design, 3<sup>rd</sup> ed.
4. H. K. Khalil. Nonlinear Svstems, 2<sup>nd</sup> ed., Prentice-Hall. 1996.
5. D. G. Luenberger, Linear and Nonlinear Programming, Addison Wesley, 2<sup>nd</sup> ed.
6. R.A. Williams and D.A. Lawrence. Linear State Space Control Systems, Wiley Publishing.

## Preliminary Major Exam in Fluid Dynamics

### Textbooks

K & C -- P.K. Kundu and I.M. Cohen, *Fluid Mechanics Third Edition*, Academic Press 2004.

L & R – H. W. Liepmann and A. Roshko, *Elements of Gasdynamics*, Dover, 2002.

M-T -- L.M. Milne-Thomson, *Theoretical Hydrodynamics*, Dover 1996.

S -- M.A. Saad, *Compressible Flow*, Prentice Hall, 1993.

V & K -- W. G. Vincenti and C. H. Kruger, *Introduction to Physical Gas Dynamics*, Krieger 1975.

W -- Frank M. White, *Viscous Fluid Flow, Third Edition*, McGraw Hill 2006.

### Topics

1. **Conservation laws and non-conservative forms.** Navier-Stokes equations, Euler equations, potential flow equations, including viscous potential flow. Nondimensional groupings of parameters, the incompressible limit, the inviscid limit. Energy and Entropy equations for both incompressible and compressible flows. K & C, Chapters 1, 2, 4; M-T, Chapters II, III.

2. **Use of non-primitive variables.** Kinematics, streamlines, planar and axisymmetric stream functions, velocity potential; key issues in vector calculus; generalized Bernoulli equation; vorticity dynamics; circulation, Kelvin's circulation theorem, Crocco's vorticity theorem; vortex lines, vortex tubes, vortex stretching; Kelvin's minimum energy theorem. K & C 3, 4, 5; M-T I, IV, IX, XIII

3. **Use of complex variables.** Complex potential. Irrotational flows: sources, sinks, doublets, irrotational vortex; wedge flows, corner flows and stagnation point flows; flow past circular cylinders with and without circulation; lift force and Kutta- Joukowski lift theorem. K & C 6; M-T V, VI, VII, VIII.

4. **Method of images.** Vortex-vortex interactions, vortex-wall interactions. K & C 6; M-T VIII, XIII.

5. **Mappings.** Joukowski transformation, flows around plates and elliptical cylinders. 2D airfoils: lift and drag; Kutta condition; theorem of Schwarz and Christoffel, flows with steps, channel flows with area changes and branches. K & C 6, 15; M-T VI, X

6. **Free surface flows.** Impinging jets; flow through an orifice. M-T XI

7. **Flow stability.** Biot- Savart Law for vortical flows; vortex sheets; Linear perturbation analysis for hydrodynamic stability, Kelvin-Helmholtz instability, Rayleigh-Taylor flow, gravity waves, centrifugal instability; dispersion relations. K & C 7, 12; M-T XIII, XIV, XV.

8. **Water (gravity) waves.** Deep-water and shallow-water limits, group velocity. K & C 7; M-T XIV, XV.

9. **Axisymmetric potential flow around bodies of revolution.** K & C 6; M-T 6; XVI, XVII, XVI, XVII.
10. **Viscosity.** Stress and strain tensors, Newtonian fluids and coefficient of viscosity; Navier-Stokes equations for heat-conducting, compressible fluid; nondimensional groupings of parameters. Boundary conditions. Diffusion of vorticity. W 1, 2, 2.
11. **Exact solutions.** Couette, Poiseuille Taylor-Couette flows. Unsteady flows: Stokes first and second problems; Duhamel integrals. Similarity. Jeffrey-Hamel flow, separation. W 3.
12. **Low-Reynolds-number flows.** Stokes flow, Oseen approximation; lubrication theory. W 3.
13. **Laminar boundary layers.** High-Reynolds-number flows over plates and wedges, Blasius and Falkner-Skan similar solutions, stagnation-point flow; integral methods, momentum and displacement thicknesses; axisymmetric flows. Boundary layers with suction and blowing. Compressible boundary layers: Crocco and Busemann integrals, Howarth and Dorodnitsin transformations. W 4, 7.
14. **Free shear flows.** Viscous jets, wakes, and mixing layers. W 4, 7.
15. **Stability of laminar flows.** Linear theory of small disturbances, Orr-Sommerfeld equation and solutions; transition to turbulence. W 5.
16. **Turbulent flows.** Vorticity equation, vortex stretching; Concept of time-averaging, elementary statistics (mean, variance, correlation, spectrum), Reynolds-averaged Navier-Stokes equations (RANS), modeling of terms, derivation and explanation of the turbulent kinetic energy equation; turbulent pipe flow, law of the wall; turbulent boundary layer, mixing-length theory. W 6.
17. **One-dimensional steady flow.** Isentropic flow, area change and choked flow, friction, heat addition; normal shocks. Rayleigh and Fanno lines. L&R 2; S 5, 6.
18. **One-dimensional, unsteady flow.** Isentropic waves, travelling shocks, contact surface, shock-tube problem; method of characteristics, Riemann invariants; onedimensional and spherical acoustics. L&R 3; S 9.
19. **Two-dimensional compressible flow.** Oblique shocks; Prandtl-Meyer isentropic waves; method of characteristics, Riemann invariants; wave reflections and interactions. L&R 4; S 7, 9.
20. **Compressible potential flow.** Small perturbations in subsonic, transonic, and supersonic regimes, slender-body linearized supersonic aerodynamics, Prandtl- Glauert similarity rule; underexpanded and overexpanded flows through converging/ diverging nozzles (internal and external flow). L&R 8; S 8.

21. **Thermodynamic couplings.** The perfect gas law, physical significance of  $c_p$  and  $c_v$ , their dependence on molecular structure and temperature. K & C 1; W 7.

22. **Kinetic theory of gases.** Derivation of Navier-Stokes equations for monatomic gas; pressure forces at wall; use of Krook model to determine Newtonian relationship between viscous stress and strain. V & K 1, 2, 9.

23. **Elementary engineering flows.** Theoretical and practical knowledge of elementary engineering flows, from low to high Reynolds numbers: flow around cylinder, sphere, plate, airfoil, finite wing; orifice flow. K & C 9, 15; W 3, 4.

## **Preliminary Major Exam in Solid Mechanics**

### **Textbooks**

BJ -- Beer and Johnston, *Mechanics of Materials*, McGraw-Hill, 2005.

CTS -- Sun, *Mechanics of aircraft structures*, John Wiley & Sons, New York, 1998.

THGM -- Megson, *Aircraft structures for engineering students*, Butterworth-Heinemann, 2007.

FT -- Fung and Tong, *Classical and computational solid mechanics*, World Scient., 2005.

MM -- Mase and Mase, *Continuum mechanics for engineers*, CRC, 2nd Ed., 1999.

DI -- Daniel and Ishai, *Engineering mechanics of composite materials*, Oxford University Press, 2006.

KKC -- Chawla, *Composite materials: Science and engineering*, Springer, 1998.

### **Topics**

1. **Basic concepts of mechanics of structures.** Introduction to stress, strain and elastic behavior. Torsion. Bending; shear stress in beams and shafts; M and V distribution in statically determinate and indeterminate beams. Shear flow in thin-walled beams (including multi-celled sections). Transformation of stress and strain (Mohr circle). Von Mises yielding criterion. Buckling of columns and simply supported plates. Elastic energy. Concepts of statical determinacy and indeterminacy. Solution of trusses and frames via displacement and force methods. *BJ, Ch. 1-11. THGM, Ch. 6.1-6.6.*

2. **Mechanics of composite materials.** Classifications of composite materials based on matrix chemistry and shape of the reinforcement. Common reinforcement and matrices for polymer matrix composites (PMC), metal matrix composites (MMC) and ceramic matrix composites (CMC). Elastic behavior of anisotropic materials. Stiffness of an orthotropic lamina: micro and macro mechanics. Strength of an orthotropic lamina: micro and macro mechanics. The shear-lag model for short fiber composites. Stiffness and strength of multidirectional laminates. The effect of temperature and humidity. Common experimental techniques for composite structures. *DI, Ch. 1-10. KKC, Ch. 1-8.*

3. **Basic concepts of Linear Elastic Fracture Mechanics.** Stress concentration and Griffith theory. Stress intensity factor. Strain energy release rate. Fracture toughness. *CTS, Ch. 6.3-4. Fatigue failure. CTS, Ch. 6.5-6.*

4. **Fundamental mathematical concepts.** Scalars, vectors and higher-order tensors. Indicical notation. Kronecker delta tensor; permutation tensor. Scalar (dot) product; cross product. Transformation of cartesian tensors. Principal values and principal directions of symmetric second-order tensors. Vector identities in tensor notation. Gauss and Stokes theorems. *MM, Ch. 2. FT, Ch. 2.1-3.*

5. **The stress tensor.** Alternate stress measures, Cauchy, first Piola, and second Piola stress tensors. Principal stresses and directions. Plane stress. Mohr's circle. Hydrostatic and deviatoric components of stress. Octahedral shearing stress. *MM, Ch. 3. FT, Ch. 3.1-3.11.*

6. **Kinematics.** Material and spatial coordinates. Lagrangian and Eulerian description. Deformation gradients. Stretches of line, area and volume. Finite strain tensors (Green and Cauchy strain tensors). Strain rates. Material derivatives of line, area and volume elements. Infinitesimal strain and its geometric interpretation. Rotations. *MM, Ch.4. FT, Ch. 4.1-6, 4.9, 16.1-6.*

7. **Fundamental conservation laws.** Conservation of mass (continuity). Conservation of linear momentum. Conservation of angular momentum. Conservation of energy. First and second Piola-Kirchhoff stress tensors. Second law of thermodynamics and restriction on elastic properties. Invariance. *MM, Ch. 5. FT, Ch. 5, 16.7.*

8. **Constitutive equations.** Elasticity: generalized Hooke's law; isotropic elastic materials; symmetry considerations; relation among elastic properties. Plasticity: yield surface; flow rules for isotropic and kinematic hardening. *MM, Ch. 6. FT, Ch. 6.1-12.* Basic notions of viscoelasticity (Maxwell, Voigt and Kelvin models). *FT, Ch. 1.*

9. **Small deformation elasticity.** Navier's equations. Boundary value problems. Specified displacement and traction boundary conditions. Potential energy for hyperelastic solids. Uniqueness of solutions. Plane elastic waves (shear and dilational wave speeds). Two-dimensional problems: plane stress and plane strain. Airy's stress function in cartesian and polar coordinates. *FT, Ch. 7.1-4, 7.8, 9.1-3.*

10. **Principle of virtual work.** *FT, Ch. 10.7.*

11. **Basic notions of the Finite Elements method.** One and two-dimensional problems with one-dimensional elements (e.g. frames). Shape functions. Assembling global matrices. THGM, *Ch. 6.7-6.8.*

## Preliminary Major Exam in Transport/Thermal Science

### Textbooks

SB&V -- R.E. Sonntag, C. Borgnakke, and G. J. Van Wylen, *Fundamentals of Thermodynamics, Sixth Edition*, John Wiley & Sons, 2002.

Ö -- M. Necati Özisik, *Heat Conduction, 2nd Edition*, John Wiley & Sons Inc, 1993.

C & J -- H. S. Carslaw and J. C. Jaeger, *Conduction of Heat in Solids, Second edition*, Oxford University Press, 1986.

KC&W -- W.M.Kays, M.E.Crawford and B. Weigand, *Convective Heat and Mass Transfer, Forth Edition*, McGraw-Hill Inc., 2004.

BS&L -- R.B. Bird, W.E. Stewart, and E.N. Lightfoot, *Transport Phenomena, Second Edition*, Wiley, 2001.

IDB&L -- F.P. Incropera, D.P. DeWitt, T.L. Bergman and A.S. Lavine, *Fundamentals of Heat and Mass Transfer, Sixth Edition*, John Wiley & Sons, 2006.

### Topics

- 1. Basic concepts of thermodynamics:** Energy, forms of energy, Closed and open systems, Equilibrium and state, Thermodynamic properties of a system (U, V, m, T, P, etc.), Entropy and enthalpy, Reversible/irreversible processes. *SB&V, Ch. 2-5, 8, 10.*
- 2. Laws of thermodynamics and power systems:** First/second/third law, First/second law analysis, Cycle analysis including Otto, Diesel and Rankine cycles, Ideal and real refrigeration cycles, Combustion process, Analysis of reacting systems. *SB&V, Ch. 5-9, 11, 14.*
- 3. Gas mixtures, chemical equilibrium and thermodynamic relations:** Gas-vapor mixtures, Requirement for equilibrium, Chemical equilibrium, The Maxwell Relation, Thermodynamic relations involving enthalpy, internal energy, and entropy. *SB&V, Ch. 12,13,15.*
- 4. Basic definitions and conservation of heat/mass transfer:** Conduction, convection, and radiation, Fundamentals of mass transfer, Energy equation and special forms of the energy equation, Differential equations of mass transfer. *IDB&L, Ch. 1, 2, 6, 14; Ö, Ch. 1; BS&L, Ch. 9, 17; KC&W, Ch. 2.*
- 5. Principles of conduction heat transfer:** Heat conduction equations in the cartesian, cylindrical, and spherical coordinate systems, Lumped system formulation, Validity of the lumped capacitance analysis, Boundary conditions of the first, second, and third kinds, Interface boundary condition. *IDB&L, Ch. 2-5; Ö, Ch. 1; C & J, Ch. 1.*
- 6. Methods of solving conduction problems:** Simple analytical solutions of the conduction energy equation for steady and unsteady problems, Separation of variables in different coordinate systems, The Duhamel's theorem, Applications of Green's function, Laplace transform. *IDB&L, Ch. 3, 5; Ö, Ch. 2-7; C & J, Ch. XIIXV. 2*

7. **Moving heat source and phase-change problems:** 1D mathematical modeling of moving heat source, Exact and approximate solutions of phase-change problem. *Ö, Ch. 10, 11; C & J, Ch. XI.*

8. **Fundamentals of convective heat transfer:** Forced vs. free convection, Laminar vs. turbulent flow, Internal vs. external flows, Dimensional analysis: characteristic quantities, dimensionless groups: Re, Pr, Ec, Nu, Gr, St, Order of magnitude scaling and negligible terms. *IDB&L, Ch. 6- 9; KC&W, Ch. 8, 10, 12, 14, 17.*

9. **Laminar external flow heat transfer:** Boundary layer flow, Enthalpy/conduction thicknesses, Exact solutions, Similarity, Integral approach for laminar flow, Boundary layer development with unheated-length, Free convection, Boussinesq approximation. *IDB&L, Ch. 7; KC&W, Ch. 8.*

10. **Laminar internal flow heat transfer:** Mass-averaged fluid temperature, Fully developed temperature profiles, Constant heat rate vs. constant surface temperature problems. *IDB&L, Ch. 8; KC&W, Ch. 10.*

11. **Turbulent external/internal flow heat transfer:** Reynolds-averaged Navier-Stokes equation, Eddy diffusivity for heat transfer, Eddy conductivity, Reynolds analogy, Two-layer model, Law of the Wall for the thermal boundary layer. *IDB&L, Ch. 7, 8; KC&W, Ch. 12, 14.*

12. **Radiation heat transfer:** Fundamental physics of thermal radiation, Intensity, Black body radiation, Radiation properties of surfaces, Radiation exchange between graydiffuse surfaces, Radiation exchange between surfaces using network method. *IDB&L, Ch. 12,13.*

13. **Diffusive mass transfer:** Steady-state molecular diffusion, Fick's law of binary diffusion, Temperature and pressure dependence of diffusivities, Diffusion in gases at low density, in binary liquids, and in colloidal suspensions, The Maxwell-Stefan equations for multi-components diffusion. *IDB&L, Ch. 14; BS&L, Ch. 17.*

14. **Convective mass transfer:** Basic definitions, such as mass/molar average velocity, mass/molar fluxes, and convective mass/molecular fluxes, Differential and simplified equation of the concentration boundary layer, Dimensional analysis: Sc and Le. *KC&W, Ch. 18; BS&L, Ch. 20.*

15. **Convective mass transfer conductance:** Mass-transfer conductance and driving force, High mass-transfer-rate convection in a laminar Couette flow, Laminar/turbulent constant-property boundary layer. *KC&W, Ch. 19.*

16. **Applications of simplified method in convective mass transfer:** Thermodynamics of the air-water-vapor system, Drying, Evaporative cooling, Burning of a volatile fuel in air, Naphthalene sublimation from a flat plate, Transpiration cooling by gas injection. *KC&W, Ch. 20.*

## Preliminary Exam in Applied Mathematics

### Textbooks

- G -- Advanced Engineering Mathematics, by Greenberg, Prentice-Hall
- C -- Linear System Theory and Design, by C-T Chen, Oxford Publishing, third Edition
- H -- Applied Partial Differential Equations with Fourier Series and Boundary Value Problems, 4<sup>th</sup> Ed., Haberman, Prentice-Hall
- F -- Partial Differential Equations for Scientists and Engineers, by S. J. Farlow, Dover paperback, 1993.

### Topics

#### A. *Linear Algebra*

1. Vectors, norms, inner-products, orthogonality, adjoint operators, and their properties. G, Sections 9.1-9.5
2. Vectors spaces, linear independence, Wronskian, span and subspace, basis. G, Sections 9.6-9.9 Matrix Analysis
3. Matrices: determinant, inverse, domain, range, null space, rank. G, Chapter 10
4. Eigenvalues and eigenvectors. G, Sections 11.1, 11.2
5. Basic properties, diagonalization. G, Sections 11.2, 11.4
6. Properties of symmetric (Hermitian) matrices, positive (semi) definite matrices, etc. G, Sections 11.3)  $Ax = b$  and the Least Squares Problem
7. Basic definition, existence and uniqueness (rank conditions). G, Chapter 8 and Section 10.5
8. Solution by optimization. G, Sections 9.10

#### B. *Ordinary Differential Equations And Dynamical Systems*

9. Phase plane and its use to study second order ODE. G, Sections 7.2, 7.3
10. Solution to general LTI systems: first order form ( $x' = Ax + Bu$ ), Leibnitz rule, the solution to the first order form. C, Section 4.2
11. Decoupling, diagonalization and modal forms. G, Section 11.5
12. LTV systems, state transition matrices and their properties. C, Section 4.5 Stability
13. General definitions. C, Chapter 5
14. LTI: eigenvalues and the complete picture. C, Sections 5.2-5.4
15. LTV systems and eigenvalues. C, Section 5.5 Nonlinear Dynamical Systems
16. Phase Portrait. G, Section 7.2
17. Equilibrium points, stability, linearization about equilibrium points, use of eigenvalues for stability of equilibrium points. G, Section 7.3
18. Duffing equation. G, Section 7.6 Solving ODE's
19. Numerical solution: Euler's method. G, Section 6.2
21. Power series solution. G, Section 4.2
22. Frobenius solution (regular singular point). G, Section 4.3

### C. *Partial Differential Equations*

23. From Physics to PDE: The linear 2nd-order diffusion equation, the Laplace and Poisson equations, the linear 2nd-order wave equation, and first-order linear and non-linear wave equation. Boundary conditions. H, Chapter 1 and 4. F, Lessons 1-4, 16, and 31-32.
24. Separation of variables, eigenvalue and eigenfunctions, superimposition principle. H, Chapters 2 and 4. G, Chapters 18 and 19. F, Lessons 5-8 and 26.
25. Fourier-series. H, Chapter 3. G, Chapter 17.
26. The Sturm-Liouville theorem, and generalize Fourier expansion. H, Chapters 5 and 8. G, Section 17.7-17.8. F, Lesson 9.
27. Multi-dimensional problems using separation of variables, double Fourier-series, Bessel functions, and Legendre polynomials. H, Chapter 7. G, Sections 4.4 and 4.6 and Chapter 20. F, Lessons 30 and 35.
28. Traveling waves, D'Alembert formula for the wave equation, vibration of finite strings, wave reflection at boundaries. H, Sections 12.1-12.5. G, Chapter 19 and Sections 18.4 and 20.4. F, Lessons 17-20.
29. Fourier transform and its application to the solution of PDEs. H, Chapter 10. G, Section 17.9-17.11. Fm Lessons 11-12 and 21.
30. Laplace transform and its application to the solution of PDEs. H, Chapter 13. G, Section 18.4 and 20.4. F, Lesson 13.
31. Greens function method for solving Poisson equations, method of images. H, Section 9.5. F, Lesson 36.
32. Method of characteristics for 1st order linear and non-linear wave equations, the traffic flow equation, shock waves. System of linear first-order wave equations.. H, Chapter 12. F, Lessons 27-29.
33. Classification of 2nd-order partial differential equations. F, Lesson 23.

### **“Synthesis and Integration” Component of the Preliminary Exam**

#### **OBJECTIVE:**

Test candidate's ability to apply knowledge of two or more fundamental areas of science and engineering toward the design of a structure, machine, apparatus, computer algorithm, or manufacturing process for a specific practical purpose. Candidate is expected to demonstrate integration and synthesis across and beyond specific course content.

#### **FORMAT:**

**Duration:** 60 minute oral exam

**Number of examiners:** A total of three: advisor plus two other faculty.

**Examiner selection process:** One examiner is nominated by the advisor and can be outside MAE. The third examiner is nominated by the Graduate Committee. The examiners are approved by the Department Chair. The names of the Examiners are communicated to the Candidate at least 1 month prior to the examination date.

## **GUIDELINES FOR EXAMINERS AND STUDENTS:**

The Examiners should provide a journal paper to the student, at least four weeks prior to the exam. The publication should be carefully selected to meet the objective stated above. It should have at least 25 formal citations in the archival literature. In addition, none of the authors of the publication should be current or former members of the candidate's research group. The student is required to begin the exam with a short presentation, using up to 15 slides or hand-out sheets to present his /her understanding of the selected paper. Still, the majority of the exam time will be spent in an interactive mode with the examiners.

During the exam, the student should describe the research objective, why it is important, why it is novel with respect to previous research, the precise formulation of the problem being addressed, the solution approach, the results, and the conclusions. The student should critically evaluate the research and suggest possible improvements and extensions of the work. The performance will be evaluated on the ability to understand, synthesize and integrate the ideas of the publication. In addition, the student will be evaluated on: effective communication, ability to think critically "on the spot", and overall problem solving skills. The student is expected to understand the derivations and assumptions of all the fundamental science and engineering supporting the publication and in addition to have some familiarity with the key references associated with the publication.

**Evaluation:** The candidate's advisor is allowed to vote. The candidate passes this component of the Preliminary Exam by having at least two out of three passing votes from the examiners.