PhD Qualifying Examination
Thermal/Fluid Sciences Thematic Area

Examination Format

The examination will consist of 9 questions from the topics listed below. (The topic list should be considered a guideline and not an exhaustive list.) Students must answer 5 of the 9 questions. If the student answers more than 5 questions, the first 5 will be graded. Students should clearly mark answers they don't want included in their examination by writing "DO NOT GRADE" and marking a single line through the answer. Students will have 2.5 hours for the examination.

Reference Materials

Students taking the TF qualifying exam are allowed to develop a one-page (one page front and back), hand-written formula sheet of math to be used during the exam. The students can include anything they consider of interest to them. The one-page formula sheet must be submitted to the Graduate Program Director at least three days before the qualifying exam. The formula sheet will be returned to the student at the start of the exam. Students may bring a heat transfer textbook for reference. No textbook or notes are allowed for fluid dynamics.

Topics

1. **Mathematics**
   a. Vector Differential and Integral Calculus
      i. Curves and surfaces
      ii. Vector fields and streamlines
      iii. Intrinsic coordinates of curves and surfaces
      iv. Tangent vectors, normal vectors, tangent planes
      v. Vector operator, gradient, div, and curl, and their geometric interpretation
      vi. Green's, Gauss' and Stokes' Theorems
   b. Fourier Analyses
      i. Trignometic series and the Fourier transform
      ii. Orthogonal polynomials and series in orthogonal polynomia
      iii. Fourier Bessel series
   c. Ordinary Differential Equations
      i. Linear equation systems with constant coefficients
      ii. Method to solve for a n^{th} order linear inhomogeneous ODE
   d. Partial Differential Equations
      i. Classifications of PDEs
      ii. Domains and boundary and initial conditions required
      iii. Method of separation of variables
      iv. Method of eigenfunction expansion
      v. Method of superposition

2. **Advanced heat conduction and radiation**
    a. Fundamentals of Heat Transfer
        i. Principle of energy conservation
        ii. Fourier law and general heat conduction equation
        iii. One dimensional steady state heat conduction problems
        iv. Transient heat conduction problems and Lumped Capacitance analysis
    b. Steady state conduction problems in Cartesian and Cylindrical Coordinate Systems: solution with Separation of Variables Method
    c. Transient Heat Conduction Problems in Cartesian and Cylindrical Coordinate Systems: solution with Separation of Variables Method and Similarity Method
    d. Heat Conduction Problems Involving Heat Sources or Sinks.
    e. Steady-state and Transient heat conduction problems: solution with Numerical Method— Finite Differences/Finite volume.
    f. Radiation ---- Basic Relations
        i. Intensity of Radiation
        ii. Blackbody Emission
        iii. Radiation Properties
        iv. Definitions of Properties for Non-black Surfaces
        v. Radiation Properties of Real Materials
    g. Radiation Exchange in an Enclosure, Radiation Exchange among Diffuse-gray (Including Blackbody) Surface; Radiation in Enclosures
3. **Fluid Mechanics**
    a. Basics of Fluid Mechanics
        i. Understand the definitions of fluid properties, e.g., pressure, viscosity, compressibility;
        ii. Given a flow field, be able to calculate the stress tensor, find reaction forces on a plane of arbitrary orientation, and perform analysis of fluid kinematics, e.g., velocity, acceleration;
        iii. Be able to carry out dimensional analysis;
        iv. Be able to use the Bernoulli equation to perform dynamic analysis of the incompressible flow;
    b. Differential Analysis of Fluid Flow
        i. Be able to manipulate vector and tensor expressions and identities;
        ii. Be able to derive and manipulate the governing equations (conservation of mass, linear momentum, and energy) in vector and index forms;
        iii. Given a flow field, be able to simplify the governing equations based on physical justifications (assumptions). Solve the resulting PDE or ODE;

iv. Given a PDE, find the similarity variable of the form $\eta = C x^m t^n$ that transforms the PDE and its boundary conditions to an ODE with new boundary conditions

c. Control Volume Analysis
   i. Be able to derive Reynolds Transport Theorem and apply it in deriving the governing equations (conservation of mass, linear momentum, energy) from a material volume point of view;
   ii. Be able to apply Reynolds Transport Theorem in both i) deriving the governing equations (conservation of mass, linear momentum, energy) and ii) solving practical problems from the fixed control volume view point.

d. External and Internal Flows
   i. Be able to describe different flow types in pipes;
   ii. Be able to describe different flow types over cylinders;
   iii. Be able to carry out flow analysis of both external and internal flows using differential analysis, control volume analysis, and dimensional analysis.

e. Boundary Layer Theory
   i. Be able to manipulate boundary layer solutions to obtain boundary layer thickness, displacement thickness for a given boundary layer profile;
   ii. Be able to estimate and discuss the magnitude of terms in the governing equations and the timescale of physical mechanisms for a given flow situation.

f. Basics of Finite Difference Method (Optional)
   i. Be able to derive the finite difference schemes for the governing equations of fluid flow;
   ii. Be able to carry out basic analysis of the finite difference schemes, e.g., order of accuracy, stability.

Ph.D. Qualifying Exam Reference Books (Any edition should be an appropriate study guide.)

1. Fundamentals of Fluid Mechanics (Chapters 1-8), by B. R. Munson et al. 7th edition, Wiley.
2. Viscous Fluid Flow, by F. M. White. 3rd edition, McGraw-Hill.
3. Computational Fluid Dynamics: The Basics with Applications (Chapter 4: Basic Aspects of Discretization), by J. D. Anderson Jr. 1st edition, McGraw-Hill.
4. Heat and Mass Transfer, by Cengel and Ghajar, 5th edition, McGraw-Hill.
5. Thermal Radiation Heat Transfer, by Howell, Siegel, and Menguc, 5th edition, CRC.