Heat and Mass Transfer

The field of Heat and Mass Transfer, as it relates to preparation for the Ph.D. degree in Mechanical Engineering or Aerospace Engineering, concerns all aspects of heat and mass transfer relevant to mechanical, nuclear, and aerospace engineering.

Summary of Major Field Body of Knowledge:

Students should master the major field body of knowledge covered in the following courses:
MAE 131A, 231A, 231B, 231C, and 233
as well as at least one additional course pertinent to the field. Possible courses include:
MAE 231G, 285, 286, 296B, 252C, 250F.

The written qualifying (preliminary) examination covers the following subset of the major field body of knowledge:
MAE 131A and the student's selection of two courses from:
MAE 231A, 231B, 231C, 233.

More details concerning the body of knowledge can be found in the **Syllabus for the Major Field**, on the next page.

Minimum Requirements for Ph.D. Major Field Students:

The student must pass a written examination in the major field and satisfy other program requirements for the Ph.D. in the MAE Department besides completing all other formal University requirements.

Format of Written Qualifying Examination:

The exam consists of a 4-hour closed book part, emphasizing fundamentals, and a 4-hour open book part, where students will be required to display proficiency in selected advanced topics.

Timing of Written Qualifying Examination:

Offered when three or more students are ready to take it or at a minimum once a year.

Link to old exams:

http://stdntsvcs.mae.ucla.edu/exam/index.htm

Ph.D. Minor Field Requirements:

The minor field requirement can be satisfied by completing MAE 131A (or equivalent) and three other courses selected from MAE 231A, 231B, 231C, 231G, and C132A/233A. The average grade for these courses must be 3.33 or better, and no grade shall be less than B-.

Syllabus for the Major Field in Heat and Mass Transfer

A. Required Fundamentals

1. Transport Properties [MAE 131A]
   Properties of Gases
   Properties of Liquids
   Properties of Metals and Nonmetals
   Properties of Porous Solids
2. Heat Conduction in Stationary Media [MAE 131A]
   One-dimensional steady conduction
   Extended surfaces
   Multidimensional steady conduction
   Transient conduction
3. The Conservation Equations [MAE 231A]
   Mass
   Momentum
   Energy
   Chemical species
4. Heat Convection [MAE 131A, 231A]
   Similitude
   Fully developed laminar flow in ducts
   Laminar boundary layer on a flat plate
   Natural convection
5. Radiative Heat Transfer [MAE 131A, 231B]
   Physics of Radiation
   Diffuse wall enclosures
   Radiation shields
   Solar radiation
6. Boiling and Condensation [MAE 131A and/or 231C]
   The pool boiling curve
   Nucleate and film boiling
   The peak and minimum heat fluxes
   Laminar film condensation
7. Mass Transfer [MAE 231A]
   Definitions of concentrations and fluxes
   Interfacial conditions
   The analogy between convective heat and mass transfer
   Simultaneous convective heat and mass transfer
8. Exchanger Design [MAE 131A]
   Exchanger balances
   Overall heat transfer coefficients
   LMTD and ε-NTU methods
   Single and two stream heat exchangers

B. Advanced topics

1. Heat Convection [MAE 231A]
   Duct entrance regions
   Laminar boundary layers with pressure gradients
   Turbulent flow in ducts
   Turbulent boundary layers
   Laminar and turbulent natural convection boundary layers
   Variable wall temperature and heat flux
   High speed flow and recovery factors
2. Radiative Heat Transfer [MAE 231B]
   Directional and spectral variation of surface properties
   The equation of radiative transfer
   Radiative heat transfer in participating media
   Engineering calculation of radiation heat transfer in combustion gases
   Coupling radiative transfer with fluid flow and heat conduction
3. Boiling and Two Phase Flow [MAE 231C]
   Nucleate boiling and bubble dynamics
   Maximum and minimum pool boiling heat fluxes
   Pool film boiling
   Forced flow evaporation and boiling
   Film condensation
   Two phase flow regimes
   Two phase flow models
4. Nanoscience for Energy Technologies [MAE 233]
   Energy transport carriers: phonons, electrons, and photons
   Classical laws, size effects, and characteristic lengths
   Heat conduction, kinetic theory, and phonon spectra
   Quantum mechanics, band structures, energy levels, and density of states
   Atoms, lattices, and crystal structures
   Statistical thermodynamics, distribution functions, internal energy, and specific heat
   Boltzmann equation and relaxation time approximation
   Interfacial energy transport and Landauer Formalism
   Thermal boundary resistance and electronics thermal management
   Applications in energy, nanotechnology, and semiconductors

C. Course Preparation

As preparation for the written examinations, the student should have taken MAE 131A (or an equivalent course), and a selection of at least two courses from MAE 231A, 231B, 231C and 233. The student is expected to have an adequate mathematics preparation for graduate work in the field. Recommended courses include MAE 182A, 182B, and 182C.

In addition to passing the written examination, students should complete six courses in the major field as indicated under Summary of Major Field Body of Knowledge above.

References:

The following books are used as texts or reference works in the courses of the major field.

1. Mills, A.F., Heat Transfer, 2nd ed., Prentice Hall, NJ (1999)
2. Mills, A.F., Mass Transfer, Prentice Hall, NJ (2001)
3. Incropera, F.P., De Witt, D.P., Bergman T.L., and Lavine, A.S., Fundamentals of Heat and Mass Transfer, 6th ed. (2007)
4. Lienhard, J.H IV and V, A Heat Transfer Textbook, free download from Internet.
5. Carslaw, H.S. and Jaeger, J.C., Conduction of Heat in Solids, Oxford University Press (1986)
6. Myer, G.E., Analytical Methods in Conduction Heat Transfer, Genium, Schenectady N.Y. (1987)
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8. Burmeister, L.C., Convection Heat Transfer, 2nd ed., J. Wiley, NY (1993)
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11. Oosthuizen, P., Introduction to Convective Heat Transfer Analysis, McGraw-Hill, NY (1999)
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15. Edwards, D.K., Radiation Heat Transfer Notes, Hemisphere, Washington D.C. (1981)
16. Modest, M.F., Radiative Heat Transfer, McGraw-Hill, NY (1993)
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19. Wallis, G., One-dimensional Two Phase Flow, McGraw-Hill, NY (1969)
20. Collier, J.G., Convective Boiling and Condensation, McGraw-Hill, N.Y. (1972)
21. Chandrasekar, S., Hydrodynamic and Hydromagnetic Stability, Oxford Press (1961)
22. Kittel, C. and Kroemer, H., Thermal Physics, 2nd ed., Freeman, N.Y. (1980)
23. Kittel, C., Solid State Physics, 7th ed., J. Wiley (1996)
24. Vincenti, W.G. and Kruger, C.H., Physical Gas Dynamics, J. Wiley, N.Y. (1965)
25. Tien, C.L., Majumdar, A., and Gerner, F., eds., Microscale Energy Transport, Taylor and Francis (1997)
26. Hirschfelder, J.O., Curtiss, C.F., and Bird, R.B., Molecular Theory of Gases and Liquids, 2nd ed., J. Wiley, NY (1964)
27. Rosner, D.E., Transport Processes in Chemical Reacting Flow Systems, Butterworth-Heinemann, Stoneham, Mass (1990)
28. Cussler, E.L., Diffusion: Mass Transfer in Fluid Systems, 2nd ed., Cambridge University Press, London (1997)