

# 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, C132A/232A, 231A, 231B

as well as 3 additional courses pertinent to the field. Possible courses include:

MAE 231C, 231G, 285, 286, 296B, 252C, 250F (at least one of 231C or 231G must be taken)

The written qualifying (preliminary) examination covers the following subset of the major field body of knowledge:

MAE 131A, C132A/232A, 231A, 231B

and a selection of 1 course from:

MAE 231C, 231G.

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/232A. 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, 132A]
  - 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, C232A]
  - 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 C132A]
  - Definitions of concentrations and fluxes
  - Interfacial conditions
  - Steady diffusion across a plane wall
  - Transient diffusion
  - Heterogeneous catalysis
  - The analogy between convective heat and mass transfer
  - Simultaneous convective heat and mass transfer
  - Adiabatic vaporization, wet-bulb temperature
8. Exchanger Design [MAE 131A, C132A]
  - Exchanger balances

Overall heat transfer coefficients  
LMTD and  $\epsilon$ -NTU methods  
Single and two stream heat exchangers  
Single stream mass exchangers - catalytic converters and evaporative coolers

## **B. Advanced topics**

Students should prepare themselves for Topics 1-3, and at least one of Topics 4 and 5.

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. Mass Transfer [MAE C132A/232A]
  - Diffusion in porous media
  - Transport in multicomponent gas mixtures
  - Laminar and turbulent boundary layers with mass transfer
  - Condensation from vapor-gas mixtures
  - Transpiration and sweat cooling
4. 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
5. Microscopic Energy Transport [MAE 231G]
  - Statistical thermodynamics fundamentals
  - Energy carriers
  - Kinetic and transport theory
  - Surface and Interface Effects
  - Applications to semiconductor and MEMS devices

## **C. Course Preparation**

As preparation for the written examinations, the student should have taken MAE 131A (or an equivalent course), MAE C132A/232A, 231A, 231B, and 231C or 231G. 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, it is recommended that the student take two advanced specialized courses pertinent to the field. Possible courses include MAE 231C or 231G (whichever one the student was not examined on), 285, 286, 296B, 252C, 250F.

## 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)
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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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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)