Study Guide for CM3110
Module 4 Heat Transfer Introduction
Morrison Spring 2021

Test subjects in this course are cumulative. Anything on a study guide from a prior exam may be the subject of a current exam.

Exam 4 will cover, in addition to Exam 1-3 topics, Fourier's law of heat transfer, microscopic energy balances, heat-transfer boundary conditions, temperature and heat flux profiles, heat-transfer dimensional analysis, and classical heat transfer solutions and heat-transfer troubleshooting.

<u>To do well on the test, you should be able to do the following:</u>

Material and system properties for heat transfer in solids and fluids (steady)

1. Define <u>heat flow</u> $\dot{Q}$; give an example of heat flow in an engineering application
2. Compare and contrast heat flow with energy
3. (stretch) Compare and contrast changes in internal energy ΔU and enthalpy ΔH

Transport law: Fourier's law of heat transfer (thermal conductivity)

4. Define the <u>thermal conductivity</u> and explain how this quantity influences the heat-transfer behavior of materials (solids and fluids); contrast it with the heat capacity.
5. Explain Fourier's law of conduction and explain its purpose
6. (stretch) In general terms, explain how non-Fourier conductors may be different from Fourier-type conductors
7. (stretch) Calculate heat flux q/A from temperature gradients and vice versa from Fourier's law of heat conduction

Temperature and heat flux profiles. If provided with a one-dimensional or two-dimensional temperature profile (also called a temperature distribution or the temperature field),

8. Sketch the temperature profile or graphically represent the temperature field
9. Calculate the heat flux through a chosen surface
10. Identify the driving forces for heat transfer and the various resistances, including expressions in rectangular and curvilinear coordinates

Microscopic energy balances

11. Define the microscopic energy balance equation and explain its utility
12. Compare and contrast the conservation of energy equation and Fourier's law of heat conduction
13. For a chosen heat flow scenario, identify and justify reasonable modelling assumptions that will allow the temperature and heat flux fields to be determined
14. For a chosen heat flow scenario, calculate the temperature and heat flux fields. You must be able to indicate your assumptions and to show how you arrive at your answer from the principles discussed in the course

Boundary conditions in heat transfer in solids and fluids

15. Explain the role that temperature and heat-flux boundary conditions play in heat-transfer modeling

16. Provide actual engineering examples of temperature boundary conditions and heat flux boundary conditions
17. Define Newton's law of cooling (linear driving force condition) and identify where it applies
18. Identify appropriate temperature and heat flux boundary conditions for a heat-flow scenario described
19. In detailed mathematical form identify appropriate temperature/temperature gradient and heat-flux boundary conditions for a heat-flow scenario described
20. From the temperature and heat flux fields in a given heat-flow scenario, calculate the total heat $\dot{Q}$ passing through a chosen surface

Using classical heat-transfer solutions. Determine temperatures, temperature distributions, and/or heat fluxes in the following circumstances

21. Steady state 1D heat transfer in a rectangular slab with temperature boundary conditions
22. Steady state 1D heat transfer in a rectangular slab with Newton's law of cooling boundary conditions
23. Steady state 1D radial heat transfer in a cylindrical shell with temperature boundary conditions
24. Steady state 1D radial heat transfer in a cylindrical shell with Newton's law of cooling boundary conditions
25. Two or more *resistances* are combined in one of the scenarios outlined above (heat transfer in series, compound devices, insulation)

Dimensional analysis in heat transfer, conditions at the boundary (complex heat-transfer systems involving forced convection)

26. Explain the purpose of dimensional analysis in heat-transfer engineering
27. Explain the meaning of "data correlation;" explain where we obtain data correlations
28. List, define, and explain the use of at least three dimensionless numbers in heat transfer
29. Explain two examples of using dimensional analysis to calculate an engineering quantity of interest in heat-transfer engineering. Indicate when the correlations apply
30. List two examples of data correlations for Nusselt number Nu for forced convection (give the name if it has one and the equation with symbols identified). Indicate when the correlations apply
31. Calculate heat transfer coefficients, h, from Nu data correlations in the literature using the appropriate reference temperatures; calculate heat flow $\dot{Q}$ using the appropriate average temperature driving force ΔT
32. Calculate heat loss through a boundary, evaluating the heat transfer coefficient from data correlations appropriate to the problem (linear driving force model, Newton's law of cooling)

Heat transfer troubleshooting

33. From among heat transfer tools (microscopic momentum balance, macroscopic energy balance, other) identify the method that will result in the missing desired quantity (amount of heat transferred, heat flux, temperature field, etc.)
34. List, in an order that works, steps for determining a quantity with the heat transfer tools at your disposal