Study Guide for CM3120 Transport II
Module 2 Unsteady State Heat Transfer
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 2 will cover, in addition to Exam 1 topics, material and system properties for unsteady heat transfer, microscopic energy balances, boundary conditions, and engineering quantities of interested for unsteady heat transfer, dimensional analysis for unsteady heat transfer, and troubleshooting for unsteady heat transfer.

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

Material and system properties for unsteady heat transfer

1. Define <u>thermal diffusivity</u> α and explain how this quantity influences unsteady heat transfer
2. Define Biot number; give symbol and units
3. Distinguish between Biot number and Nusselt number; be specific in your answer

Microscopic energy balances, boundary conditions, and engineering quantities of interest (unsteady)

4. Simplify the microscopic energy balance for elementary scenarios (unsteady); arrive at a differential equation to solve for the temperature distribution
5. Identify and apply temperature boundary conditions for unsteady heat transfer scenarios
6. Identify and apply Newton's law of cooling boundary conditions (linear driving force heat transfer model) for unsteady heat transfer scenarios
7. Calculate and sketch temperature fields for elementary scenarios (unsteady)
8. Calculate engineering quantities of interest (amount of heat transferred $\dot{Q}$, specific temperatures of interest) given temperature and velocity fields (unsteady)

Using classical unsteady heat-transfer solutions.

Determine specific temperatures of interest or engineering quantities of interest by applying literature solutions to complex microscopic unsteady energy balances:

9. Using the solution to heat transfer in a semi-infinite solid (Geankoplis Figure 5.3-3, p364)
10. Using Heisler charters for temperature at the center of a: large flat plate (Figure 5.3-6, p368), cylinder (Figure 5.3-8, p371), or sphere (Figure 5.3-10, p374)
11. Using Gurney and Lurie charts for heat transfer to a: large flat plate (Figure 5.3-5, p367), long cylinder (Figure 5.3-7, p370), or sphere (Figure 5.3-9, p373)
12. Compare and contrast the Heisler charts and the Gurney and Lurie charts

13. Describe the relative advantages of solutions presented in charts (e.g. Heisler and Gurney and Lurie charts), complete solutions from the literature (Carslaw and Jaeger), and (stretch) direct simulation (e.g. by COMSOL)

Dimensional Analysis in unsteady heat transfer

14. Define <u>kinematic viscosity</u> and (stretch) explain its role in the microscopic momentum balance
15. Explain the purpose of dimensional analysis in unsteady state heat transfer in solids
16. Explain the three regimes of Biot number and why they are significant
17. Define and explain the *lumped parameter* analysis; explain how Biot number is defined for lumped parameter analysis
18. (stretch) Explain the phrase “lumped parameter”

Macroscopic unsteady energy balance

19. List the contributions to the macroscopic unsteady energy balance and indicate how each is typically evaluated
20. Simplify and solve the macroscopic energy balance for elementary scenarios
21. Carry out lumped parameter analysis calculations for engineering quantitites of interest or temperatures of interest

Unsteady state heat transfer troubleshooting

22. Compare and contrast steady and unsteady heat transfer scenarios.
23. 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, specific temperature of interest, etc.) for unsteady state scenarios
24. List, in an order that works, steps for determining a quantity with the heat transfer tools at your disposal

<u>References:</u>

- Christie J. Geankoplis, *Transport Processes and Unit Operations*, 4th Edition, Prentice Hall, New York (2003).
- H. S. Carslaw and J. C. Yaeger, *Conduction of Heat in Solids*, Oxford Clarendon Press, 1959.