HEAT AND MASS TRANSFER
ENME 352

Lecture : 3 | **Year : III**
Tutorial : 1 | **Part : II**
Practical : 3/2

Course Objectives:
The objective of this course is to provide students with a clear understanding of the mechanisms of heat transfer and mass transfer under both steady and transient conditions. It emphasizes the application of heat transfer principles in thermal design, including fins and other engineering systems, while also introducing methods for thermal analysis and appropriate sizing of heat exchangers. The course familiarizes students with the fundamental concepts of mass transfer, enabling them to analyze and solve practical engineering problems where heat and mass transfer processes play a critical role.

1 Conduction **(15 hours)**

- 1.1 Modes of heat transfer
- 1.2 Fourier’s law and thermal conductivity
- 1.3 Differential equations of heat conduction, boundary conditions and its solution
- 1.4 One-dimensional steady state condition without heat generation
  - 1.4.1 Plane wall
  - 1.4.2 Cylinder
  - 1.4.3 Sphere
- 1.5 Concept of thermal resistance, overall heat transfer coefficient
- 1.6 Critical radius, variable thermal conductivity
- 1.7 One-dimensional steady state condition with heat generation
- 1.8 Two-dimensional steady state condition
- 1.9 Transient conduction
  - 1.9.1 Lumped capacitance model
  - 1.9.2 Transient problem and their analytical solutions
  - 1.9.3 Application of Heisler charts
- 1.10 Numerical methods in conduction
  - 1.10.1 Steady state one dimensional and two-dimensional problems
  - 1.10.2 One dimensional transient problem for explicit and implicit cases

2 Convection **(10 hours)**

- 2.1 Boundary layer concepts
- 2.2 Natural convection
  - 2.2.1 Concept and governing equations
  - 2.2.2 Applications in cases of vertical and horizontal plate

- 2.2.3 Applications in a horizontal cylinder
- 2.3 Forced convection:
  - 2.3.1 Implications of dimensionless numbers
  - 2.3.2 Laminar flow heat transfer in circular pipe and flat plate
  - 2.3.3 Turbulent flow heat transfer in circular pipe
  - 2.3.4 Turbulent flow heat transfer in pipes of other cross section
  - 2.3.5 Heat transfer across a cylinder and sphere
  - 2.3.6 Heat transfer across banks of tubes

3 Radiation (7 hours)

- 3.1 Definitions and concept of spectrum
- 3.2 Laws of radiation
  - 3.2.1 Black body radiation
  - 3.2.2 Stefan Boltzman law
  - 3.2.3 Planck's law
  - 3.2.4 Wien's displacement law
  - 3.2.5 Lambert cosine Law
- 3.3 Radiation exchange between black surfaces
- 3.4 Applications of shape factor
- 3.5 Radiation exchange between grey surfaces (Radiosity-irradiation method)
- 3.6 Gas radiation
- 3.7 Concept and applications of radiation shield

4 Applications of Heat Transfer (7 hours)

- 4.1 Fins
  - 4.1.1 Types and applications of fins
  - 4.1.2 Heat dissipations from fins
  - 4.1.3 Fin performance: Fin effectiveness and fin efficiency
- 4.2 Heat exchangers
  - 4.2.1 Types of heat exchangers
  - 4.2.2 LMTD method of heat exchanger analysis (Parallel, counter-flow)
  - 4.2.3 Effectiveness
  - 4.2.4 NTU method of heat exchanger analysis (Parallel, counter-flow)
  - 4.2.5 Overall heat transfer coefficient
  - 4.2.6 Fouling factors

5 Condensation and Boiling (2 hours)

- 5.1 Boiling heat transfer
- 5.2 Pool boiling and flow boiling
- 5.3 Correlations in boiling
- 5.4 Condensation heat transfer
- 5.5 Nusselt's theory of condensation
- 5.6 Correlations in condensation

6 Mass Transfer (4 hours)

6.1 Basic concepts
6.2 Diffusion mass transfer
6.3 Fick's law of diffusion
6.4 Steady state molecular diffusion
6.5 Convective mass transfer
6.6 Momentum, heat and mass transfer analogy
6.7 Convective mass transfer correlations
6.8 Limitations of heat and mass transfer analogy

Tutorial (15 hours)

1. Numerical problems on one dimensional, Cartesian co-ordinate system of heat transfer calculation for conduction
2. Numerical problems on two-dimensional, cylindrical co-ordinate system for conduction heat transfer
3. Prediction of heat transfer coefficient using empirical relations for different cases of convectional heat flow
4. Estimation of fins effectiveness and efficiency
5. Numerical validation of different laws of radiation
6. Design of heat exchanger based on LMTD method
7. Design of heat exchanger based on NTU method

Practical (22.5 hours)

1. Comparison between thermal conductivities of different types of materials
2. Investigation of temperature distribution along the extended surface
3. Free and forced convection
4. Determination of LMTD and heat transfer in parallel flow and counter flow
5. Calculation of emissivity of grey body
6. Calculation of heat transfer during boiling
7. Calculation of mass and energy balance in a cooling tower
8. Steady and unsteady state heat conduction simulation using open-source software

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1	15	16
2	10	12
3	7	10
4	7	10
5	2	4
6	4	8
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Çengel, Y. A., Ghajar, A. J. (2015). Heat and mass transfer: Fundamentals and applications. Singapore: McGraw-Hill Education.
2. Holman, J. P. (1968). Heat transfer (Latest Edition). United Kingdom: McGraw-Hill.
3. Nag, P. K. (2002). Heat transfer. India: Tata McGraw-Hill.
4. Rajput, R. K. (2019). A textbook of heat and mass transfer. India: S. Chand Publishing.