# PROCESS HEAT TRANSFER

## ENCH 255

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

**Course Objectives:**

The objective of this course is to equip students with the skills to solve one-dimensional and two-dimensional heat transfer problems both analytically and numerically. Students will learn to apply energy balance equations and rate laws to solve problems related to steady and unsteady state heat transfer as well as phase change processes. Additionally, it covers the use of correlations to solve problems related to different heat exchangers, enabling students to address practical heat transfer challenges.

**1 Fundamentals of Heat Transfer (2 hours)**

1.1 Introduction to conduction, convection and radiation
1.2 Conservation of energy for a control volume
1.3 Analysis of heat transfer problems

**2 Steady State One-Dimensional (1D) Conduction (7 hours)**

2.1 Conduction rate equation
2.2 Thermal properties of matter
2.3 Heat diffusion equations and boundary conditions
2.4 1D conduction for planar, cylindrical and spherical geometries
2.5 Composite systems
2.6 Critical radius of insulation
2.7 Conduction with thermal energy generation
2.8 Heat transfer from extended surfaces

**3 Steady State Two-Dimensional (2D) Conduction (4 hours)**

3.1 Finite difference equations
3.2 Nodal network
3.3 Finite difference form of heat equation
3.4 Energy balance method
3.5 Solving the finite difference equations

**4 Time Dependent Conduction (2 hours)**

4.1 Lumped capacitance method
4.2 Lumped capacitance analysis

## 5 Fundamentals of Convection (4 hours)

- 5.1 Convection boundary layers
- 5.2 Introduction to convection coefficients
- 5.3 Laminar and turbulent flow
- 5.4 Boundary layer equations
- 5.5 Introduction to dimensionless parameters

## 6 External Forced Convection (3 hours)

- 6.1 Parallel flow over flat plates
- 6.2 Flow across cylinders and spheres
- 6.3 Flow across tube banks

## 7 Internal Forced Convection (4 hours)

- 7.1 Mean velocity and mean temperature
- 7.2 General thermal analysis
- 7.3 Laminar flow in tubes
- 7.4 Turbulent flow in tubes

## 8 Natural (Free) Convection (4 hours)

- 8.1 The governing equations for laminar boundary layers
- 8.2 Laminar free convection on a vertical surface
- 8.3 Correlations for external free convection flows: flat plates, cylinders, spheres
- 8.4 Correlations for internal free convection flows: parallel plates, concentric cylinders and concentric spheres

## 9 Boiling and Condensation Processes (3 hours)

- 9.1 Boiling modes
- 9.2 Pool boiling
- 9.3 Pool boiling correlations
- 9.4 Forced convection boiling
- 9.5 Condensation on planar and radial systems

## 10 Heat Exchangers (4 hours)

- 10.1 Types of heat exchangers
- 10.2 Heat exchanger analysis: Log mean temperature difference (LMTD) and effectiveness – Number of transfer units (NTU) methods
- 10.3 Heat exchanger design and performance calculation

## 11 Fundamentals of Radiation (4 hours)

11.1 Radiation intensity, blackbody radiation, emission from real surfaces
11.2 Absorption, reflection and transmission by real surfaces
11.3 Kirchhoff's law
11.4 Gray surface

## 12 Radiative Transfer Between Surfaces (4 hours)

12.1 View factor
12.2 Blackbody radiation exchange
12.3 Radiation exchange between opaque, diffuse and gray surfaces
12.4 Multimode heat transfer

## Tutorial (15 hours)

1. Fundamentals, steady state 1-D and 2-D; transient conduction
2. Fundamentals, external, internal and natural convections
3. Types of boiling and calculations, condensation
4. LMTD and NTU method calculations
5. Fundamentals and radiation between surfaces

## Practical (22.5 hours)

1. Verification of conduction laws, temperature profile development and thermal conductivity determination
2. Free and forced convection from plates/tubes/cylinders
3. Verification of Stefan Boltzmann law
4. Energy balance, temperature profiles development and analysis of different types of heat exchanger
5. Heat dissipation analysis and temperature profiles development of different types of fins
6. Experimental and theoretical heat transfer coefficient for drop wise and film wise condensation
7. Analysis of heat transfer problems by using computing tools (Case study)

## 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 and 2 | 9 | 12 |
| 3 and 4 | 6 | 8 |
| 5 and 6 | 7 | 10 |
| 7 and 8 | 8 | 10 |
| 9 and 10 | 7 | 10 |
| 11 and 12 | 8 | 10 |
| **Total** | **45** | **60** |

* There may be minor deviation in marks distribution.

**References**


1. Incropera, F.P., DeWitt, D.P., Bergman, T.L., Lavine, A.S. (2017). Incropera's Principles of Heat and Mass Transfer. John Wiley & Sons.
2. Cengel, Y.A., Ghajar, A.J. (2019). Heat and Mass Transfer: Fundamentals and Applications. McGraw Hill Education Private Limited.
3. McCabe, W.L., Smith, J.C., Harriott, P. (2017). Unit Operations of Chemical Engineering. McGraw Hill Inc.
4. Kern, D.Q. (2019). Process Heat Transfer. McGraw Hill Book Company. McGraw Hill Inc.
5. Carta, G. (2021). Heat and Mass Transfer for Chemical Engineers: Principles and Applications.