PROCESS HEAT TRANSFER

Course Code: 19CH1107

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Course Outcomes:

At the end of the course the student shall be able to

CO1 estimate the heat transfer rate by conduction through different geometries.

CO2 determine individual and overall heat transfer coefficients in laminar and turbulent flow conditions.

CO3 estimate heat transfer coefficient for fluids without and with phase change

CO4 analyze radiation heat transfer between different surfaces.

CO5 Design heat transfer equipment such as double pipe heat exchanger and shell & tube heat exchanger

UNIT-I **10 Lectures**

Basic modes of heat transfer: Conduction, convection and radiation.

Steady-State Conduction: One dimensional conduction in a slab, cylinder and spherical geometries without heat source, Formulation of Dirichlet, Neumann and Robin boundary conditions, The concept of heat transfer resistance and overall resistance in these systems, Optimum insulation thickness in cylindrical and spherical geometries, Thermal contact resistance, One Dimension Conduction in a slab, cylinder and spherical geometries with heat source, One dimensional heat conduction in a slab with a linearly varying thermal conductivity, Fins and their importance, The concept of fin efficiency and fin effectiveness.

Unsteady-State Conduction: General formulation of a one dimensional transient heat conduction model, Qualitative picture of the solution expected for different boundary conditions, Lumped heat capacity formulation and its validity for an unsteady heat conduction problem in a rectangular slab, Numerical problems on unsteady heat transfer using lumped heat capacity model.

Learning outcomes: After the completion of the Unit I, the student will be able to

1. Relate different modes of heat transfer (L2)
2. Derive rate of heat transfer by conduction for different geometries (rectangular, cylindrical, spherical) and for composite walls (L6)
3. Solve unsteady heat transfer in a slab (one-dimensional heat conduction) (L3)

UNIT-II **10 Lectures**

Convective Heat Transfer over flat plates: Thermal boundary layer, Laminar and turbulent convective heat transfer over a flat plate maintained at a constant heat flux, Laminar and turbulent convective heat transfer over a flat plate maintained at a constant temperature

Heat and momentum analogies: The Reynolds-Colburn analogy, The relation between drag force and the convective heat transfer coefficient.

Laminar and turbulent convective Heat Transfer inside ducts and tubes: Laminar and turbulent convective heat transfer for flow inside ducts and tubes maintained at constant wall heat flux and at constant wall temperature.

Natural Convection Systems: Free Convection from horizontal and vertical plates, Free Convection in enclosed spaces.

Learning outcomes: After the completion of the Unit II, the student will be able to

1. Demonstrate the importance of turbulent flows in enhancing the heat transfer rates (L2)
2. Demonstrate the importance of analogies (L2)
3. Estimate heat transfer coefficients and rate of heat transfer rates for flow in tubes (L5)
4. Identify the difference between forced and free convection heat transfer (L3)

UNIT-III **10 Lectures**

Heat Exchangers: Various types of heat exchangers, The Overall Heat-Transfer Coefficient, Fouling Factors. The Log Mean Temperature Difference method: Problems on double pipe heat exchanger, 1-2 and 2-4 shell and tube heat exchanger using the LMTD approach. Effectiveness-NTU Method: Problems on double pipe heat exchanger, 1-2 and 2-4 shell and tube heat exchanger using the effectiveness-NTU method. Basics of Compact Heat Exchangers and their importance in the industry, Formulation of a design and rating problems in heat exchangers, Heat exchanger selection criteria.

Learning outcomes: After the completion of the Unit III, the student will be able to

1. Demonstrate the working principles of heat exchange equipment (L2)
2. Contrast countercurrent and parallel flows (L2)
3. Estimate individual & overall heat transfer coefficients and rate of heat transfer (L3)
4. Identify different types of multi pass heat exchangers (L1)

UNIT- IV **10 Lectures**

Radiation: Physical mechanism of thermal radiation, The concept of a black surface, diffuse surface and gray surface, Radiation emitted by a black body, The concept of absorptivity, transmissivity, reflectivity and radiosity.

Radiation shape factor: Shape factor relations, The reciprocity relations, Summation rule, symmetry rule and the superposition rule, Shape factor calculations for parallel plates, parallel coaxial discs, concentric cylinders with finite length and perpendicular rectangles with a common edge.

Radiation heat transfer exchange between two black surfaces

Radiation Heat Transfer in Two-Surface Enclosures: Small object in a large cavity, two infinitely large parallel plates, infinitely long concentric cylinders and concentric spheres.

Radiation shields: Radiation between parallel infinite planes with and without a radiation shield.

Learning outcomes: After the completion of the Unit IV, the student will be able to

1. Define the phenomenon of radiation in black & gray bodies, opaque solids and between surfaces (L1)
2. Estimate view factors for various geometries (L3)
3. Demonstrate the importance of radiation shields (L3)
4. Develop combined heat transfer rate by conduction, convection and radiation (L6)

UNIT-V **10 Lectures**

Boiling heat transfer: Subcooled and saturated boiling, flow boiling and pool boiling, Boiling curve for pool boiling, The basics of burnout in flow boiling.

Condensation heat transfer: Film condensation, Derivation of the mathematical model of Nusselt theory for film condensation on a vertical plate, Drop-wise condensation, The effect of non condensable gases on the rate of condensation.

Evaporation: Mass and energy balances for single and two effect evaporators. The concept of steam economy in multiple effect evaporators, Numerical problems on single effect evaporator and two effect evaporators with and without boiling point elevation.

Learning outcomes: After the completion of the Unit V, the student will be able to

1. Find heat transfer rate to boiling liquids and from condensing vapors (L3)
2. Demonstrate the importance of multiple effect evaporation (L3)
3. Determine the performance (capacity, economy) of a given evaporator (L5)

Text Books:

1. McCabe W.L., Smith J.C. and HarriottP., *Unit Operations in Chemical Engineering*, 7th Edition, McGraw Hill,2005.
2. J.P. Holman, *Heat Transfer*, 10th edition, McGraw-Hill, New York, 2010.
3. M. Necati Ozisik, *Heat Transfer- A Basic Approach*, McGraw-Hill, New York

References:

1. Geankoplis,C.J., *Transport processes and Unit operations*, 3rd edition, PHI,2002.
2. Kern D Q, *Process Heat Transfer*, Tata McGraw-Hill, New Delhi, 1997