ADVANCED HEAT TRANSFER

I Semester

Course Code: 19ME2203

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Prerequisites: Heat Transfer

Course Outcomes: At the end of the course the student shall be able to

CO1: Explain heat conduction with heat source, fin heat transfer, 2-D and multi-dimensional heat conduction, lumped capacity systems.
CO2: Discuss heat flow in a semi-infinite solid, Heisler chart solutions, heat transfer in laminar and turbulent flow over a flat plate, and in cross flow.
CO3: Analyze developed laminar flow in a circular tube, high speed flow over a flat plate, pool boiling and film condensation.
CO4: Discuss two-phase flow regimes, models and pressure drop, correlation equations for convective boiling and condensation, and radiation shape factor.
CO5: Explain network method for radiation through transparent and absorbing media, and working principle and properties of heat pipe.

UNIT-I: (10-Lectures)

Heat source systems: One dimensional steady heat conduction - plane wall with heat source – cylinder with heat source.
Conduction-convection systems: Infinitely long rectangular fin – rectangular fin with insulated tip - triangular fin – fin effectiveness and efficiency
Two-dimensional steady state heat conduction: Steady state two-dimensional heat conduction equation – boundary conditions – numerical solution by finite difference method.
Multi-dimensional steady state heat conduction: Conduction shape factor – conduction shape factor for a three-dimensional wall and for different other geometries - conduction shape factors for buried objects
Transient heat conduction systems with negligible internal resistance: Lumped heat capacity analysis.
Learning outcomes: At the end of this unit, the student will be able to

1. Identify systems with heat source, and analyse different types of fins (L3)
2. Explain two dimensional heat conduction, and illustrate the use of conduction shape factors in multi-dimensional heat conduction systems. (L2)
3. Analyse transient lumped heat capacity systems (L4)

UNIT-II: (10-Lectures)

Negligible surface resistance: Heat flow in a semi-infinite solid with temperature boundary conditions
Finite surface and internal resistance: Heisler chart solutions for heat flow across plane wall, radial flow in a long cylinder and radial flow in a sphere
Laminar flow over a flat plate: Hydrodynamic and thermal boundary layers in laminar flow on a flat plate – exact solution by similarity method – approximate solution by von Karman integral method – momentum and thermal boundary layers in laminar flow over a flat plate
Turbulent flow over a flat plate: Analogy between momentum and heat transfer - turbulent boundary layer by integral method
Cross flow: Cross flow over cylinders and spheres – velocity profile and stagnation point – pressure drag and skin friction drag – average heat transfer coefficient – flow across tube banks – inline and staggered arrangements.

Learning outcomes: At the end of this unit, the student will be able to

1. Distinguish between the cases of negligible surface resistance and finite surface and internal resistance. (L4)
2. Illustrate aspects of laminar and turbulent flows over a flat plate. (L2)
3. Explain cross flow over cylinders, and across tube banks. (L2)

UNIT-III: (10-Lectures)

Laminar flow in a circular tube: Fully developed laminar flow in a circular tube – temperature profile for the case of constant wall heat flux – Nusselt numbers for the cases of constant wall heat flux and temperature. Heat transfer in flow of liquid metals in a tube
Heat transfer in high speed flow over a flat plate: Steady flow energy equation – evaluation of heat transfer coefficient in laminar and turbulent flows
Boiling: Incipience of pool boiling – bubble dynamics – Rayleigh's equation - Regimes of saturated pool boiling – Rohsenow's correlation
Condensation: Nusselt's analysis for laminar film condensation on a vertical plate – condensate Reynolds number – film condensation inside horizontal tubes.

Learning outcomes : At the end of this unit, the student will be able to
1. Categorize flow in a circular tube, heat transfer in liquid metals and high speed flow. (L4)
2. Summarize bubble dynamics and regimes of pool boiling. (L2)
3. Classify condensation of stationary vapor on a plate and flowing vapor in tubes. (L2)

UNIT-IV: (10-Lectures)
Two-phase flow regimes: Definitions of adiabatic, diabatic two-phase flows, void fraction – Flow regimes and flow pattern maps in vertical and horizontal flows
Two-phase flow models: Homogeneous flow, separated flow and drift flux models for two-phase flow
Two-phase flow pressure drop: Martinelli parameter – Lokhart-Martinelli correlation for two-phase flow pressure drop
Correlation equations: Chen and Shah correlations for convective boiling - Chen and Shah correlations for convective condensation
Radiation shape factor: Radiation heat exchange between black isothermal surfaces - radiation shape factor – Hottel crossed string method for shape factor determination – reradiating black surface.

Learning outcomes: At the end of this unit, the student will be able to
1. List various two-phase flow regimes and demonstrate different two-phase models. (L4)
2. Analyse pressure drop in two-phase flow and utilize correlation equations for convective boiling and condensation. (L4)
3. Determine radiation shape factor for reradiating black surfaces. (L5)

UNIT-V: **(10-Lectures)**

Radiation network method: Gray surfaces - irradiation and radiosity – space resistance and surface resistance - radiation network for two isolated gray surfaces – radiation network for two gray surfaces connected by a reradiating surface – effect of radiation on temperature measurement
Radiation through absorbing media: Radiation exchange between two surfaces through an absorbing, transmitting medium of gas - absorption in a gas layer - radiation network for an absorbing and transmitting medium - Combined convection and radiation heat transfer
Heat pipe: Working principle – working fluid - wick structures – operating ranges - operating characteristics of heat pipes – operating limits – capillary pressure – sonic limit – entrainment limit – capillary limit.

Learning outcomes: At the end of this unit, the student will be able to

1. Construct radiation networks for heat transfer between gray surfaces. (L3)
2. Estimate radiation heat transfer through absorbing and transmitting media. (L6)
3. Explain the working principle of heat pipe and discuss its operating limits. (L2)

TEXT BOOKS:

1. Holman, J.P., *Heat Transfer*, Tenth Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2017.
2. Sachdeva, T.R., *Fundamentals of Engineering Heat and Mass Transfer*, Fifth Edition, New Age International, 2017. .

REFERENCE BOOKS:

1. Incropera, F.P., Dewitt, D.P., Bergman, T.L., Lavine, A.S., Seetharamu K.N. and Seetharam T.R., *Fundamentals of Heat and Mass Transfer*, First Edition, Wiley India, 2013.
2. Yunus A Cengel, Afshin J Ghajar, *Heat and Mass Transfer*: *Fundamentals and Applications*, Fifth Edition, McGraw Hill Education, 2017.
3. Bahman Zohuri, *Heat Pipe Design and Technology*, CRC Press, 2011.