Course No.	Course Name	L-T-P Credits	Year of Introduction
CH202	PROCESS HEAT TRANSFER	3-1-0-4	2016

Prerequisite : Nil

Course Objectives

- To introduce the fundamental concepts of various modes of heat transfer.
- To offer a prefatory on the principle and application of heat.
- To emphasise the fundamental theory, analysis and applications of heat transfer
- To present a physical picture of the convection process
- To step into the aspects of process design principles of various heat transfer equipment.

Syllabus

Modes of heat transfer - conduction - thermal conductivity - steady-state conduction - critical thickness of insulation - transient heat conduction- convection - forced convection and natural convection heat transfer - analogy between heat and momentum transfer - dimensional analysis - empirical equations for heat transfer coefficient - Radiation heat transfer - heat exchange equipment - extended surface heat exchangers - condensers, shell and tube and contact type. Heat transfer in extended surfaces (fins). Evaporation – boiling-condensation

Expected Outcomes:

At the end of the course the student will be able to:

1. Identify and distinguish various modes of heat transfer, examine the mechanisms involved and the associated governing laws.
2. Use appropriate governing equations and analyse the different modes of heat transfer in different geometries and systems under steady and transient processes.
3. Compare the different transfer processes based on the concept of analogy
4. Interpret the concepts of evaporation, various types, selection and the concepts involved in the basic design of single and multi-effect evaporators.

References:

1. McCabe W.L., Smith J.C. &Harriott P., Unit Operations in Chemical Engineering, McGraw Hill
2. Hollman J.P., Heat Transfer, McGraw Hill
3. Coulson J.M. & Richardson J.F., Chemical Engineering, Vol. I and II, ELBS, Pergamon Press
4. Geankopolis C J, Transport Processes and Separation Process Principles, Prentice Hall of India, 4th Edition, Eastern Economy Edition (2004)
5. Incropera F P and DeWitt D P, Introduction to Heat Transfer, 2nd Ed John Wiley New York (1996).
6. Welty J.R., Engineering Heat Transfer, John Wiley
7. M.Necati. Ozizik, Heat transfer - A basic Approach, McGraw-Hill College (1985)
8. Kern D.Q., Process Heat Transfer, McGraw Hill
9. Datta B.K., Heat Transfer: Principles and Applications, Prentice Hall India

Module	Content	Hours	Sem. Exam Marks
I	Basic Concepts**:** Overview of applications of heat transfer in different fields of engineering, modes of heat transfer-conduction, convection and radiation, heat transfer with and without change of phase. Material properties of importance in heat transfer, Thermal conductivity, Specific heat capacity, Isotropic and anisotropic materials.	8	15%
	Conduction Heat Transfer: General heat conduction equation in Cartesian, cylindrical and spherical coordinates (derivation is required only for Cartesian geometry).		
	Boundary Conditions - Different Boundary conditions applied in heat transfer problems. Formulation of heat transfer problems - with and without generation of heat (uniform and non-uniform heat generation) at steady and unsteady state for different boundary conditions.		
	One dimensional steady state heat conduction without generation of heat**:** Fourier heat conduction equation, thermal conductivity of solids, liquids and gases-comparison between them, effect of temperature on thermal conductivity; thermal diffusivity.		
	Conduction through systems of constant thermal conductivity**:** -conduction through plane, cylindrical and spherical wall, combined boundary condition systems (conduction-convection systems), conduction through composite slab:-multilayered plane, cylindrical and spherical shells. Electrical analogy to heat flow. Numerical problems of practical importance based on the above topics.		
II	Thermal insulation**:** Analysis of Critical radius of insulation for cylinders, optimum thickness of insulation. Concept of optimum thickness of insulation. Concept of thermal contact resistance Numerical problems based on the above aspects.	8	15%
	Unsteady State heat Conduction**:** Analysis of transient heat flow with negligible internal resistance-lumped capacity analysis, concept of Biot Modulus and Fourier number-Numerical problems of practical importance. Features of Heisler charts. Use of Heisler charts for determination of temperature distribution and energy transfer (Numerical problems not required)		
	Convection**:** Mechanism, overview of continuity, momentum and energy balance equation,		
	Boundary layer concepts - thermal and velocity boundary		

	layers, boundary layer thickness, relationship between hydrodynamic and thermal boundary layer thickness for flow over flat plates. The convective heat transfer coefficient - reference temperatures, thermal boundary layers for the cases of flow over a flat plate and flow through pipe, dimensionless numbers in heat transfer and their significance		
FIRST INTERNAL EXAMINATION			
III	Dimensional analysis: Rayleigh and Buckingham's pi theorem, its limitations, application of dimensional analysis to forced convection. Forced Convection: General methods for estimation of convection heat transfer coefficient, Correlation equations for heat transfer in laminar and turbulent flow for external and internal flows for constant heat flux and wall temperature conditions- flow in a circular tube (both developing and developed flows with constant wall temperature-its analysis and constant heat flux conditions) and non-circular tubes, flow over flat plates, flow over cylinder, spheres and tube banks. Numerical problems of practical interest. Natural Convection: Dimensional analysis, natural convection from vertical and horizontal surfaces under laminar and turbulent conditions for plates, cylinders under constant heat flux and wall temperature conditions, physical significance of Grashoff and Rayleigh numbers. Numerical problems of practical interest. Analogy between momentum and heat transfer- Development of Reynold's and Prandtl analogy. Overview of Colburn and Von-Karman analogies (No derivation required). Comparison of different analogy expressions. Numerical problems.	8	15%
IV	Heat transfer by radiation: Introduction- theories of radiation, electromagnetic spectrum, thermal radiation, spectral emissive power, surface emission- total emissive power, emissivity. Radiative properties- Emmision, irradiation, radiosity, absorptivity, reflectivity and transmissivity. Concept of black and grey body, radiation intensity, Laws of black body radiation, non-black surfaces- Grey, white and real surface, Lambert's cosine law., radiation between black surfaces and gray surfaces, radiation shape factor, reciprocity theorem, radiation between large parallel gray planes-derivation of expression for rate of radiant energy exchange, concentric cylinders and spheres (no derivation required), radiation	9	20%

	between a small gray body and a large gray enclosure. Radiation shields.		
	Classification of heat exchangers**:** Classification according to transfer processes: Indirect-Contact heat exchangers, direct-contact heat exchangers; Classification according to number of fluids; Classification according to surface compactness: gas-to-fluid exchangers, liquid-to-liquid and phase-change exchangers; Classification according to construction features: tubular heat exchangers, plate-type heat exchangers, extended surface heat exchangers, regenerators; Classification according to flow arrangements: single-pass exchangers, multi-pass exchangers; Classification according to heat transfer mechanisms.		
	Basic construction of a shell and tube heat exchanger with details of the various parts.		
	Concept of overall heat transfer coefficient - Derivation of expression for overall heat transfer coefficient, Concept and types of fouling - fouling factors, determination of overall heat transfer coefficient with and without fouling		
	Derivation of expression for LMTD		
	Concept of logarithmic mean temperature difference and its correction factor - Heat exchanger analysis using LMTD method in parallel flow, counter flow exchanger, cross flow and multi-pass heat exchangers, Temperature – distance plots for different flow arrangements in single and multi-pass heat exchangers. NTU. Determination of area, length, number of tubes required for a given duty in different configurations using LMTD and NTUmethod of analysis.		
SECOND INTERNAL EXAMINATION			
V	Heat transfer in extended surfaces: Types of extended surfaces (fins), General conduction analysis of fins, boundary conditions. Reduction of general equation to determine temperature distribution and heat flux for fin of uniform cross section for infinitely long fin and fin with insulated tip (Derivations required). Expression for temperature distribution and heat flux for fin of uniform cross section with convective boundary condition at the fin tip (No derivation is required). Effectiveness of fins-justification for providing fins on a surface; efficiency of fins-expression for fin efficiency. Principle of fins for temperature measurement.	13	20%

	Evaporation: Principle of Evaporation, types of evaporators- their construction and operation:- Natural circulation evaporators, short tube vertical or calandria type evaporators, basket type vertical evaporators, long tube vertical evaporators, forced circulation evaporators, falling film evaporators, climbing or rising film evaporators, agitated thin film evaporators, the plate evaporator. Evaporator auxiliaries: - vacuum devices, steam traps and its variants, entrainment separators.		
	Single effect and multiple effect evaporators - Performance of evaporators, capacity and economy of evaporators, factors affecting the performance of evaporators. Overall heat transfer coefficient, effect of liquid head and boiling point elevation. Material and energy balances for single effect evaporator and the calculations on single effect evaporator. Numerical problems of practical interest. Temperature profile in evaporators.		
	Multiple effect evaporators: temperature profile of liquids in the evaporator, enthalpy of solution, Different feeding arrangements in multiple effect evaporators – their merits and demerits.		
VI	Boiling and Condensation: - Dimensionless parameters in boiling and condensation. Pool boiling - Boiling curve, hysteresis in the boiling curve, mechanism of nucleate boiling - modes of pool boiling, pool boiling correlations - Nucleate pool boiling - correlations - Yamagata et al correlation, Rohsenow correlation. Correlation for critical heat flux for nucleate pool boiling - Zuber correlation. Correlation for minimum heat flux - Zuber correlation. Correlations for film pool boiling.	10	20%
	Condensation: Physical mechanisms, types of condensation, factors affecting condensation, laminar film condensation on a vertical plate - detailed analysis by Nusselt to determine the heat transfer coefficient. Laminar film condensation on radial systems - condensation on spheres, horizontal tubes and for a vertical tier of horizontal tubes, condensation inside a horizontal tube, correlations, film condensation inside horizontal tubes. Drop wise condensation – correlations- Numerical problems. Comparison between drop-wise and film type condensation, promoters and inhibitors used in condensation.		
END SEMESTER EXAMINATION			

Evaluation Scheme

- **Internal Evaluation: Total Marks: 50**
  - (i) *Total Marks for Assignment/Seminar/Project/Case study or any other appropriate tool used for the evaluation of the course outcomes:* **10**
    A minimum of above two tools shall be used. If more than 2 tools are used, proportionate change shall be made in the marks so that the total contribution of marks for item (i) above remains at 10.
  - *(ii) Marks for Tests: Two tests each carrying 40% weightage shall be conducted with total contribution of* **40 marks***.*

- **External Evaluation :** University Examination
  Maximum Marks : 100
  Exam Duration : 3 Hours

Question Paper Pattern:

There shall be **Three questions** uniformly covering Modules 1 and 2, each carrying 15 marks, of which the student has to answer any **Two questions**. At the most 4 subdivisions can be there in one main question with a total of 15 marks for all the subdivisions put together.
(2 x15= 30 Marks)

There shall be **Three questions** uniformly covering Modules 3 and 4, each carrying 15 marks, of which the student has to answer any **Two questions**. At the most 4 subdivisions can be there in one main question with a total of 15 marks for all the subdivisions put together.
(2 x15= 30 Marks)

There shall be **Three questions** uniformly covering Modules 5 and 6, each carrying 20 marks, of which the student has to answer any **Two questions**. At the most 4 subdivisions can be there in one main question with a total of 20 marks for all the subdivisions put together.
(2 x20= 40 Marks)