Course Code	Course Name	L-T-P-Credits	Year of Introduction
BT202	Bioprocess Heat Transfer	3-1-0-4	2016

Prerequisite : Nil

Course Objectives

- To expose students to fundamentals of heat transfer with adequate emphasis on numerical exercises.
- To give an understanding of the importance of different modes of heat transfer, analysis and design of heat transfer equipment, and energy changes in living systems.

Syllabus

Different modes of heat transfer, formulation of heat transfer problems using different boundary conditions with and without generation of heat, Fourier's law, solution of steady state one dimensional heat conduction with heat generation, Elementary treatment of unsteady state heat conduction-Lumped capacity analysis, General principles of thermal/heat sterilization, Design of Continuous sterilizer, Film concept of heat transfer, Individual and overall heat transfer coefficient, Heat transfer equipment, Thermodynamics of microbial growth and product formation.

Expected outcome

Upon successful completion of this course, the students should be able to

- Understand the basic principles involved in the mechanism of heat transfer.
- Calculate the rate of heat transfer and area of heat transfer equipment.
- Formulation of heat transfer problems and solve them.
- Describe the typical equipment used in heat transfer operations.
- Understand energy changes in living systems.

Reference Books

1. Dutta B. K., *Heat Transfer- Principles and Applications*, Prentice Hall of India, 2000.
2. Holman J. P., *Heat Transfer*, McGraw Hill, 1992.
3. Coulson J. M. and J. F. Richardson, *Chemical Engineering,* Vol. 1, Pergamon Press, 1999.
4. K. A. Gavhane, *Hear Transfer*, Nirali Prakashan, 2008
5. Doran P. M., *Bioprocess Engineering Principles*, 2/e, Elsevier- Academic Press, 2013.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Importance of heat transfer-various applications and principle and mechanism of the different modes of heat transfer viz. Conduction, Convection and Radiation. General heat conduction equation in various coordinates Formulation of heat transfer problems using different boundary conditions with and without generation. Solution of steady state one dimensional heat conduction with heat generation. Numerical problems	10	15%
II	Lumped capacity analysis Chilling and freezing of food and biological materials Thermal processing and sterilization of biological materials Insulation materials and Fins detailed heat transfer analysis is not desired)	10	15%

	Fundamental considerations in convective heat transfer, significant parameters in convective heat transfer such as momentum diffusivity, thermal diffusivity, Prandtl number, Nusselt number, dimensional analysis of convective heat transfer-Natural and Forced convection,		
	FIRST INTERNAL EXAM		
III	Boundary layer concept LMTD, LMTD correction factor Individual heat transfer coefficients, relationship between individual and overall heat transfer coefficients Dimensional analysis Buckingham's pi theorem Empirical correlations Numerical problems	10	15%
IV	Boiling heat transfer Regimes of pool boiling of saturated liquid Correlations for estimating the boiling heat transfer coefficients. Types of condensation Nusselt's equation with derivation Correlations for determination of condensing coefficients	8	15%
	SECOND INTERNAL EXAM		
V	Detailed classification of heat exchangers Elementary design Use of plate-heat exchangers for biological fluids. Types of evaporators and theory Multiple effect evaporators Calculations on single effect evaporators Heat transfer through extended surfaces.	10	20%
VI	Energy changes in living systems – free energy, enthalpy, entropy and their relationship, free energy changes in biochemical reactions such as hydrolysis of ATP and other high energy phosphate compounds, application of calorimetry to gain basic understanding of energy flow in a biological system, Effect pH and concentration on net free energy changes	8	20%
	END SEMESTER EXAMINATION		

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

Note : Each question can have a maximum of 4 subparts, if needed.