Course Title	TRANSPORT PHENOMENA	Semester	VII
Course Code	MVJ20CH71	CIE	50
Total No. of Contact Hours	50 L : T : P :: 40 : 10 : 0	SEE	50
No. of Contact Hours/week	5	Total	100
Credits	4	Exam. Duration	3 Hours

Course objective is to:

- To introduce the students about basic laws of momentum, heat and mass transfer.
- To determine the heat transfer rate and temperature distribution for different heat transfer situations.
- To determine the mass transfer rate and concentration distribution for different mass transfer situations.
- To study the different analogies between mass, momentum and mass transfer.

Module-1	RBT Level: L-1, L-2, L3	10 Hours

Introduction: Momentum Energy and Mass Transport Newton's law of viscosity (NLV). Newtonian and Non-Newtonian fluids. Fourier's law of heat conduction (FLHC), Fick's law of diffusion (FLD), Effect of temperature and pressure on transport properties of fluids. Numerical problems on the application and use of NLV, FLHC and FLD.

Laboratory Sessions/ Experimental learning: Demonstration of the experimental determination of thermal conductivity.

Applications: In many practical situations, the calculation of friction or energy losses in conduits, or the heat and mass transport at interfaces can be greatly simplified by using the so-called transport coefficients.

Video link / Additional online information:

https://nptel.ac.in/courses/103/105/103105128/

Module-2	RBT Level: L-1, L-2, L3	10 Hours

Velocity Distribution in Laminar Flow: Different Flow situations, Steady state Shell momentum balances, Boundary conditions applicable to momentum transport problems, Flow over a flat plate, Flow through a circular tube, Flow through Annulus. Steady State.Shell Energy Balances: General Boundary conditions applicable to energy transport problems of chemical engineering. Heat conduction through compound walls. Overall heat transfer coefficient.

Laboratory Sessions/ Experimental learning: Demonstration of shell momentum

balances and boundary conditions through videos. **Applications:** A common application of laminar flow is in the smooth flow of a viscous liquid through a tube or pipe. The walls of furnaces, boilers and other heat exchange devices consist of several layers. **Video link / Additional online information:** https://nptel.ac.in/courses/103/105/103105128/		
Module-3	**RBT Level: L-1, L-2, L3**	**10 Hours**
Temperature Distribution in Solids and in Laminar Flow: Different situations of heat transfer: Heat conduction with internal generation by electrical and nuclear energy sources, Heat conduction in a cooling fin: Forced and free convection heat transfer. Concentration **Distributions in Laminar Flow**: Steady state Shell mass balances. General Boundary conditions applicable to mass transport problems of chemical engineering. Equimolar counter diffusion. Numerical problems. **Laboratory Sessions/ Experimental learning:** Demonstration of shell mass balances and boundary conditions through videos. **Applications:** Convective heat and mass transfer applications are heat exchangers, migration of moisture through air contained in fibrous insulation, energy efficient drying processes, underground spread of pollutants, packed-bed nuclear reactors, cooling of radioactive waste containers, microelectronic devices during their operation etc. **Video link / Additional online information:** https://nptel.ac.in/courses/103/105/103105128/		
Module-4	**RBT Level: L-1, L-2, L3**	**10 Hours**
Concentration Distributions in Laminar Flow: Diffusion through stagnant gas and liquid films, Diffusion with homogeneous reaction, Diffusion with heterogeneous reaction Diffusion into falling film – Forced convection mass transfer. Numerical problems. **Laboratory Sessions/ Experimental learning:** Demonstration of the effect of homogenous and heterogenous reaction using video. **Applications:** Applications of diffusion are sintering to produce solid materials (powder metallurgy, production of ceramics), chemical reactor design, catalyst design in chemical industry. **Video link / Additional online information:**		

https://nptel.ac.in/courses/103/105/103105128/		
Module-5	RBT Level: L-1, L-2, L3	10 Hours

Analogies between Momentum, Heat and Mass Transport: Analogies between Momentum, Heat and Mass Transport - Reynold's, Prandtl's and Chilton & Colburn analogies. Equations of Change: Equation of continuity, Equation of motion; Navier – Stokes equation. Macroscopic Balance for Isothermal Systems (Mass, Momentum and Mechanical Energy Balance).

Laboratory Sessions/ Experimental learning: Demonstration of analogy between heat and momentum transfer through videos.

Applications: The common applications of equations of change are used in pipes, tubes and ducts with flowing fluids or gases, rivers, overall procedure as diaries, power plants, roads, logistics in general, computer networks and semiconductor technologies and some other fields.

Video link / Additional online information:

https://nptel.ac.in/courses/103/105/103105128/

Course outcomes:

CO1	Explain the basic transport equations for momentum, heat & mass transfer.
CO2	Develop the mathematical model to develop flux equations for steady state momentum and energy transfer in various situations.
CO3	Develop mathematical models to determine transfer fluxes and temperature, concentration distribution for heat sources and systems involving diffusion.
CO4	Develop the flux equations for steady state mass transfer in various situations.
CO5	Apply equation of change in solving steady state problems &analyse analogies between momentum, heat and mass transport.

Text Books:

1	Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2006). *Transport phenomena* (Vol. 1). John Wiley & Sons.

Reference Books:

1	B. M Suryavashi and L. R Dongre,(2015),*Transport phenomena*,7th edition, Niraliprakashann, 2015.
2	Brodkey, R. S., & Hershey, H. C. (2003). *Transport phenomena: a unified aprroach*. Brodkey publishing.

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes – 2 Nos.		2*2=4
Activities/ Experimentations related to course/ Seminar presentation – 2 Nos.		2*5=10
Mini Projects/ Case studies/Assignments – 3 Nos.		3*2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	--	--	--	--	--	--	--	--	--	--
CO2	3	3	--	--	--	--	--	--	--	--	--	--
CO3	3	3	3	3	--	--	--	--	--	--	--	--
CO4	3	3	--	--	--	--	--	--	--	--	--	--
CO5	3	3	--	--	--	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	PROCESS CONTROL	Semester	VII
Course Code	MVJ20CH72	CIE	50
Total No. of Contact Hours	50	SEE	50
No. of Contact Hours/week	5	Total	100
Credits	4	Exam. Duration	3 Hours

Course objective is to:

- To determine possible control objectives, input variables (manipulated variables and disturbances).
- To model the dynamic behaviour of a process.
- To deal with control equipment and various controllers and their functions and applications.
- To understand the frequency response and analyze stability of closed loop and open loop systems.

Module-1	RBT Level: L1, L2, L3	10 Hours

Introduction to process control and modelling consideration: Introduction to chemical process control, Process modelling and an example, linearization of a non-linear model, linearization and its application in process control, Laplace Transforms - Standard functions. **First Order Systems:** Development of transfer functions, Open loop systems, Thermometer, level, mixing tank, STR, I order systems in series. Response for various input forcing functions, first order systems and their transient response for standard input functions, first order systems in series.

Experiential learning: To determine the step response of a first order system mixing in a tank.

Applications: The application of process control is to maintain a process at the desired operating conditions, safely and efficiently, while satisfying environmental and product quality requirements

Video Links/Any other special information (Papers):

https://nptel.ac.in/courses/103/103/103103037/

https://www.youtube.com/watch?v=sj0PsMFpTKY

Module-2	RBT Level: L1, L2, L3	10 Hours

Second Order Systems: Characteristics of manometer and damped vibrator. Transfer functions. Response for various input forcing functions, response for step input for under damped case – Terms associated with it. Transportation lag. **Closed Loop System:** Development of block diagram for feed-back control systems, servo and regulatory problems, transfer function for controllers and final control element, principles of pneumatic controllers **Experiential learning**: To study the characteristics of a damped vibrator. **Applications:** Second order and closed loop systems are implemented widely in chemical industries such as mining, dredging, oil refining, pulp and paper manufacturing, chemical processing and power generating plants. **Video Links/Any other special information (Papers):** https://nptel.ac.in/courses/103/103/103103037/ https://ocw.mit.edu/courses/chemical-engineering/10-450-process-dynamics-operations-and-control-spring-2006/lecture-notes		
Module-3	RBT Level: L1, L2, L3	10 Hours
Syllabus Content: **Stability:** Stability of linear control systems. Routh Test. **Frequency response:** Introduction to frequency response of closed-loop systems, control system design by frequency response techniques, Bode diagram, Principle of Nyquist diagram, stability criterion **Experiential learning**: Demonstration of simulated closed loop response. **Applications:** Frequency response techniques have been used to characterize an external recycle reactor and various chemical equipment. **Video Links/Any other special information (Papers):** https://nptel.ac.in/courses/103/103/103103037/ http://www.infocobuild.com/education/audio-video-courses/chemistry/ProcessControlInstrumentation-IIT-Kharagpur/lecture-24.html		
Module-4	RBT Level: L1, L2, L3	10 Hours
Control System Design By Frequency Response: Bode criterion. Gain and Phase margins, Tuning of controller settings, Ziegler – Nichols controller tuning, Cohen-Coon controller tuning. **Root Locus:** Rules for plotting and problems.		

Experiential learning: To demonstrate the tuning of controllers using videos. **Applications:** A process control engineer is using the frequency response analysis to select the most appropriate values for the adjustable parameters of a controller **Video Links/Any other special information (Papers):** https://nptel.ac.in/courses/103/103/103103037/ https://www.youtube.com/watch?v=sUDoTw_LIbk

Module-5	**RBT Level: L1, L2, L3**	**10 Hours**

Advanced Control System: Introduction to advanced control systems, cascade control, feed forward control. **Introduction to computer control of chemical processes:** Digital Computer control loops **Experiential learning**: To demonstrate the multi loop control system-cascade control using videos. **Applications:** In computer process control, a digital computer is used to direct the operations of a manufacturing process and production operations involving materials such as chemicals, petroleum, foods, and certain basic metals. **Video Links/Any other special information (Papers):** https://nptel.ac.in/courses/103/103/103103037/ https://www.youtube.com/watch?v=B5jxoBiWB9g

Course outcomes:

CO1	Interpret the process control and modelling considerations and model the dynamics of a first order process.
CO2	Develop the transfer functions for a second system and derive the transient response of servo and regulator control with various control modes.
CO3	Analyze the stability for a given linear control systems using Routh Hurwitz criteria and the frequency response using Bode and Nyquist diagrams.
CO4	Analyze the control system design by frequency response and plot root locus diagram for different process.
CO5	Discuss cascade control, feed forward control and the digital digital computer control loops.

Text Books:

1	Coughanowr, D. R., & Koppel, L. B. (1965). *Process systems analysis and control* (Vol. 2). New York: McGraw-Hill.

2	Stephanopoulos, G. (1984). *Chemical process control* (Vol. 2). New Jersey: Prentice hall.
Reference Books:	
1	Benenati, R. F. (1973). Process modeling, simulation and control for chemical engineers, William L. Luyben, McGraw-Hill, New York, 1973. 558 pp.
2	Coulson, J. M., Richardson, J. F., & Peacock, D. G. (1979). Chemical Engineering, Vol 3 (Chemical Reactor Design, Biochemical Reaction Engineering Including Computational Techniques and Control).

Scheme of Evaluation		
Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Assignments (2 Nos.)		5X2=10
Practical Examinations		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO MAPPING												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	--	--	--	--	--	--	--	--	--	--
CO2	2	3	--	--	--	--	--	--	--	--	--	--
CO3	3	3	2	2	--	--	--	--	--	--	--	--
CO4	3	3	2	2	--	--	--	--	--	--	--	--
CO5	3	3	--	--	--	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	ADVANCED MEMBRANE SEPARATIONS	Semester	VII
Course Code	MVJ20CH731	CIE	50
Total No. of Contact Hours	40 L:T:P :: 20:20:0	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- Acquire in-depth knowledge in the areas of membrane separation mechanisms, membrane types and modules, membrane contactors / reactors and applications.
- Be able to select membrane processes for solving separation problems pertaining to water and Wastewater, Biotechnology and Biomedical Engineering, Gas Separations etc.

Module-1	RBT Level: L1, L2, L3	8 Hours

Introduction: Historical development of membranes, their classification with definitions.

Membrane transport theory: The solution-diffusion model, structure-permeability relationships in solution-diffusion membranes, and pore-flow membranes.

Experiential Learning: Demonstration of various membrane materials.

Applications: Overview of membrane science and its historical development

Video link / Additional online information:

https://www.sciencedirect.com/science/article/abs/pii/S001191640901282X

https://www.youtube.com/watch?v=napOhqnDR9I

Module-2	RBT Level: L1, L2, L3	8 Hours

Membrane processes: Theory, system design, and applications of microfiltration, ultrafiltration and micelle-enhanced ultrafiltration, nanofiltration, reverse osmosis, ion exchange membrane processes (electrodialysis, fuel cell membranes, and membranes in chlor-alkali processes). Numericals.

Experiential Learning: Demonstrating the discussed membrane techniques and their mechanism of separation through animated videos.

Applications: Industrial application of membrane science and technology for water and wastewater treatment.

Video Links/Any other special information:

https://www.thembrsite.com/membrane-filtration-technology-wastewater-treatment/

https://www.youtube.com/watch?v=cAjiMapprxM		
Module-3	RBT Level: L1, L2, L3	8 Hours
Membrane processes: Theory, system design, and applications of gas permeation, liquid membranes, membrane distillation, membrane contactors, membrane reactors and membrane bioreactors, and submerged membranes. **Experiential Learning:** Demonstrating the discussed membrane techniques and their mechanism of separation through animated videos. **Applications:** Industrial application of membrane science and technology for biotechnology and biomedical engineering. **Video Links/Any other special information:** https://www.thembrsite.com/membrane-filtration-technology-wastewater-treatment/ https://www.youtube.com/watch?v=cAjiMapprxM		
Module-4	RBT Level: L1, L2, L3	8 Hours
Concentration polarization and fouling: Polarisation phenomena and fouling concentration polarization (liquid separations), Gel layer model, Osmotic pressure model, Boundary layer resistance model, Characteristic flux behaviour in pressure driven membrane operation (gas separation process), membrane fouling, methods to reduce fouling. **Experiential Learning:** Demonstrating membrane fouling and their types. **Applications:** Solving membrane fouling issues industrially. **Video Links/Any other special information:** https://www.nature.com/articles/s41598-019-52369-1 https://www.youtube.com/watch?v=g9y-WXTKh5Q		
Module-5	RBT Level: L1, L2, L3	8 Hours
Membranes and modules: Isotropic membranes, anisotropic membranes, inorganic membranes, liquid membranes, hollow fibre membranes, membrane modules and their applications in the current world. Case study. **Experiential Learning:** Demonstrating types of membrane modules and their functioning. **Applications:** Industrially important membranes processes **Video Links/Any other special information**: https://synderfiltration.com/learning-center/articles/module-configurations-		

process/hollow-fiber-membranes/ https://www.youtube.com/watch?v=pYzZ9zJpCoY	
Course outcomes:	
CO1	History of membrane technology evaluation and practice.
CO2	Explain Nanofiltration, Reverse osmosis, Dialysis, piezodialysis, electrodialysis, Pervaporation and membrane distillation.
CO3	Design of Gas, Liquid and Ion exchange membranes in economical perspective
CO4	Design of membranes, Membrane fouling, Methods to reduce fouling.
CO5	Design of process modules and configurations of Membrane reactors for biotechnology.
Text Books:	
1	Richard W. B. (2012). Membrane Technology and Applications 3rd Edition. (John Wiley & Sons, Ltd., United Kingdom).
2	Li, N. N., Fane, A. G., Ho, W. W., & Matsuura, T. (Eds.). (2011). *Advanced membrane technology and applications*. John Wiley & Sons.
Reference Books:	
1	Philip, C. Wankat. (2005). Rate-Controlled Separations (Springer).
2	Ronald W Rousseau. (2008). Handbook of separation process technology. (Wiley India Pvt. Ltd.).
3	Web Link and Video Lectures: https://nptel.ac.in/courses/103103163/

Scheme of Evaluation:

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Assignments (2 Nos.)		5X2=10
Journals/Progress notes		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	--	--	--	--	--	--	--	--	--
CO2	3	3	3	--	--	2	2	--	--	--	--	1
CO3	3	3	3	--	--	2	2	--	--	--	--	1
CO4	3	3	3	--	--	--	--	--	--	--	--	--
CO5	3	3	3	--	--	2	2	--	--	--	--	1

High-3, Medium-2, Low-1

Course Title	PHARMACEUTICAL CHEMISTRY	Semester	VII
Course Code	MVJ20CH732	CIE	50
Total No. of Contact Hours	40 L:T:P :: 40:0:0	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- Learn formulations, tablet and capsule making.
- Learn development, testing of cosmetics.
- Learn manufacturing technology.
- Learn patent intellectual property rights and regulatory affairs.

Module-1	RBT Level: L1, L2, L3	8 Hours

Electrophilic substitution reaction: Preparation of cyclo alkane. Bayer's strain theory and orbital picture of angle stream. **Electrophilic substitution reaction mechanism & application**: Dehydrogenation of alkyl halides. 1-2 elimination kinetics: E2 and E1mechanisms. Isotope effect. Dehydration of alcohols. Ease of dehydration.

Experiential Learning: Dehydration of Alcohols to Alkenes

Applications: Students will understand the mechanism of dehydration

Video link / Additional online information:https://nptel.ac.in/content/storage2/courses/104103022/download/module11.pdf

Module-2	RBT Level: L1, L2, L3	8 Hours

Nucleophilic addition reaction: Mechanism. Important chemicals. Oxidation-Reduction reactions. Rheology of Fluids in Mixing and Blending.

Experiential Learning: Studies on nucleophilic addition reaction

Applications: Students will understand the importance of nucleophilic addition reaction. These reactions are considered very important in organic chemistry since they enable the conversion of carbonyl groups into a variety of functional groups

Video Links/Any other special information:
https://nptel.ac.in/content/storage2/courses/103108100/module6/module6.pdf

Module-3	RBT Level: L1, L2, L3	8 Hours

Preparation: Test for purity and medical uses of Chlorobutal, Dimercopral, and Glycerol trinitrate.

Experiential Learning: Glycerol trinitrate synthesis **Applications:** Students will be able to understand the synthesis of Glycerol trinitrate and its medical uses. **Video Links/Any other special information:** https://nptel.ac.in/courses/103/107/103107082/		
Module-4	**RBT Level: L1, L2, L3**	**8 Hours**
Preparation: Test for purity and medical uses of Urea, ethylene diamine dihydrate, vanillin, and paraldehyde. **Preparation:** Test for purity and medical uses of lactic acid, citric acid, salicylic acid, saccharin sodium. **Experiential Learning:**Urea synthesis **Applications:** Students will be able to understand the synthesis of Urea and its applications **Video Links/Any other special information:** https://nptel.ac.in/courses/103/107/103107086/		
Module-5	**RBT Level: L1, L2, L3**	**8 Hours**
Preparation: Test for purity and medical uses of Ethyl borate, dimethyl phthalate, and aspirin. **Experiential Learning:**Aspirin synthesis **Applications:** Students will be able to understand the synthesis of aspirin and its medical uses. **Video Links/Any other special information:** https://nptel.ac.in/content/storage2/courses/104103018/pdf/mod3.pdf		

Course outcomes:	
CO1	Explain electrophilic substitution reaction, its kinetics and mechanism.
CO2	Summarize mechanism & reactions of nucleophilic addition reaction
CO3	Illustrate the rheology of fluid mixing
CO4	Explain Preparation and Purity testing for compounds in medical application
CO5	Outline preparation, purity test and uses of acidic & ethyl borate, dimethyl phthalate & Aspirin

Text Books:	
1	Jain, N. K. (Ed.). (2006). *Pharmaceutical product development*. CBS publishers & distributors.
2	Morisson, T.R. and Boyd,R. (1992). Organic Chemistry, 6th edition. Prentice Hall of India Pvt Ltd., New Delhi.

Reference Books:	
1	Lachman, L., Lieberman, H. A., &Kanig, J. L. (1976). *The theory and practice of industrial pharmacy* (pp. 210-212). Philadelphia: Lea &Febiger.
2	Clayden, J., Greeves, N., Warren, S., &Wothers, P. (2001). Organic chemistry.
3	Web Link and Video Lectures: https://nptel.ac.in/courses/102/108/102108077/ https://nptel.ac.in/courses/104/102/104102113/ https://nptel.ac.in/noc/courses/noc19/SEM2/noc19-bt23/

Scheme of Evaluation:

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Assignments (2 Nos.)		5X2=10
Journals/Progress notes		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	--	--	--	--	--	--	--	--	--	3	--
CO2	2	2	--	--	--	--	--	--	--	--	3	--
CO3	2	2	--	--	--	--	--	--	--	--	3	--
CO4	2	2	--	--	--	--	--	--	--	--	3	--

High-3, Medium-2, Low-1

Course Title	NOVEL SEPARATION TECHNIQUES	Semester	VII
Course Code	MVJ20CH733	CIE	50
Total No. of Contact Hours	40 L : T : P :: 40 : 00 : 00	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 hrs

Course Objective is to

- identify the multiple factors influencing the choice of separation techniques.
- able to qualitatively and quantitatively address the fundamental aspects of specialty separation processes

Module 1	RBT Levels: L1, L2, L3	8 Hours

Adsorptive Separations: Review of fundamentals. mathematical modelling of column factors. pressure swing & thermal swing adsorption. counter current separations. **Chromatography:** Chromatography fundamentals, different types, gradient & affinity chromatography, design calculations for chromatographic columns.

Experiential learning: Performing simple adsorption experiment using Graphite for removal of dye at various temperatures.

Applications: Adsorption chromatography has many applications. Generally, it is used for determining the concentration of a compound (or its purity), separating out a mixture into individual components, and identifying what is in a mixture. There are three main types of adsorption chromatography - column, thin layer, and gas-solid.

Video link / Additional online information:

https://www.youtube.com/watch?v=IcUwC1c2qTc

Module-2	RBT Levels: L1, L2, L3	8 Hours

Membrane Separation Processes: Types, thermodynamic considerations. mass transfer considerations. design of RO &UF. ion selective membranes. micro filtration. electro dialysis. pervaporation. gaseous separations. **External Field Induced Separations:** Electric & magnetic field separations. centrifugal separations and its calculations.

Experiential learning: Identifying membranes in domestic wastewater treatment and their mechanism of separation.

Applications: Membrane separation technology is extensively used in food industry such as water purification, concentration and clarification of fruit juices, clarification of alcoholic beverages, production of protein concentrates, recovery of sugar from candy, recovery of oilseed protein

Video link / Additional online information:

https://www.youtube.com/watch?v=0-H195JR5i0

https://www.youtube.com/watch?v=tATDFANzHOA

Module 3	RBT Levels: L1, L2, L3	8 Hours

Surfactant Based Separations: Fundamentals. surfactants at inter phases and in bulk. liquid membrane permeation. foam separations. micellar separations. **Vapour Deposition:** Chemical vapor deposition (CVD) basics, atmospheric pressure chemical vapor deposition (APCVD), low pressure chemical vapor deposition (LPCVD), plasma enhanced chemical vapor deposition (PECVD), mass transfer control and reaction kinematics control.

Experiential learning: Learning about biosurfactants**,** demonstrate the plasma enhanced chemical vapor deposition by using NPTEL videos.

Applications: CVD has applications across a wide range of industries such as: coatings – coatings for a variety of applications such as wear resistance, corrosion resistance, high temperature protection, erosion protection and combinations thereof.

Video link / Additional online information:

https://www.youtube.com/watch?v=GIcVxvl7n84

https://www.youtube.com/watch?v=Ukvs6Rct4w8

Module-4	RBT Levels: L1, L2, L3	8 Hours

Super Critical Fluid Extraction: Component of super critical fluid extraction (SFE), properties and modes of SFE, methods of developments of SFE, thermodynamics and physico chemical principles. process description. application. case study.

Experiential learning: A case study on supercritical fluid extraction versus traditional solvent extraction of caffeine from tea leaves.

Applications: The use of supercritical CO_2 as an extraction solvent for natural products is the oldest and the most developed process on an industrial scale, with applications especially in the food industry. decaffeination of coffee: this is the first example of the industrialization of supercritical fluids

Video link / Additional online information:

https://www.youtube.com/watch?v=0RCsmoqRGBY

Module-5	RBT Levels: L1, L2, L3	8 Hours

Mechanical–Physical Separation Process: Introduction, classification, filtration in solid liquid separation. settling & sedimentation in particle fluid separation.

Other Separations: Separation by thermal diffusion, electrophoresis, crystallization.

Experiential learning: Identifying some examples related to solid-liquid separation in day-to-day life.

Applications: Processes which depend primarily on physical forces to accomplish the desired separation of components are used quite commonly in most phases of the food industry. These processes are normally referred to as mechanical separations and include filtration, sedimentation, and centrifugation.

Video link / Additional online information:

https://www.youtube.com/watch?v=0WAc06ldbLs

Course Outcomes:	
CO1	Explain fundamentals of various types of advanced separation techniques.
CO2	Understand the given industrial separation/problem and apply concepts of advanced separation techniques.
CO3	Explore usage of alternative separation techniques to the existing ones.
CO4	Analyse and design pervaporation, chromatography, and dialysis-based separation processes.
CO5	Examine merits and limitations of novel separation techniques.

Scheme of Evaluation:		
Details		**Marks**
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., $\sum$ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Activities/ Experimentations related to course/ Assignment -2 Nos. /Presentation- 1 Nos		3X2=6
Mini Projects/ Case studies/ Journal Report - 2 Nos.		2X5=10
Semester End Examination	SEE (50)	50
Total		100

Text Books:	
1	Rousseau, R. W. (Ed.). (1987). Handbook of separation process technology. John Wiley & Sons.
2	Geankoplis, C. J. (2003). Separation Process Principles.

Reference Books:	
1	Staude, E. (1991). Marcel Mulder: basic principles of membrane technology.
2	Wankat, P. C. (1990). Rate-controlled separations. Kluwer Academic Pub.
3	Wankat, P. C. (1986). Lg Scale Adsorption &Chromatogrpahy. CRC-Press.

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	--	--	--	--	--	--	--	--	--	--
CO2	2	2	2	--	--	--	--	--	--	--	--	--
CO3	2	--	--	--	--	--	--	--	--	--	--	--
CO4	3	--	3	--	--	--	--	--	--	--	--	--
CO5	--	--	3	--	--	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	NANOFABRICATION	**Semester**	VII
Course Code	MVJ20CH734	**CIE**	50
Total No. of Contact Hours	40 L : T : P :: 40 : 00 : 00	**SEE**	50
No. of Contact Hours/week	4	**Total**	100
Credits	3	**Exam. Duration**	3 Hours

Course objective is to:

- Understand knowledge on the basic concept of nano fabrication
- Learn the physical and chemical method for synthesis of nano structure
- Acquire knowledge of bottom up and lithography technique

Module-1	**RBT Level: L-1, L-2, L3**	**8 Hours**

Basic concepts of nano fabrication: Drexler-Smalley debate; realistic projections; outline of various preparation techniques; basic concepts of nano-structured materials; nucleation: surface nucleation, growth, grain size distribution; nano-particle transport in low density media; nano phase thermodynamics; coagulation of nano particles; determination of grain size; aggregate formation; mass fractal morphologies. Requirements for an ideal semiconductor nano structure; clean room technology

Laboratory Sessions/ Experimental learning: Demonstrate the concept of nano fabrication and its application

Applications: For formation of nano structure

Video link / Additional online information:

1. Duke University- https://www.youtube.com/watch?v=ZhpW095xp0U
2. NPTEL IISc: https://www.youtube.com/watch?v=sRVToVzaknM

Module-2	**RBT Level: L-1, L-2, L3**	**8 Hours**

PHYSICAL TECHNIQUES: Physical processes in semiconductor nano structures. Introduction; thin film deposition methods; fundamentals of film deposition; thermal evaporation; spray pyrolysis; flame pyrolysis; molecular beam epitaxy; pulsed laser deposition; sputter deposition; different types sputtering processes; thermal forming processes; plasma processes; physical methods for the preparation of nano tubes; types of nano tubes; new forms of carbon nano tubes; properties of nano tubes; plasma arcing; laser methods; pyrolytic synthesis; zeolites & template powders; layered silicates; soft chemical & combustion methods. Laser fusion target fabrication techniques; inorganic capsule fabrication; and cluster formation by laser ablation.

Laboratory Sessions/ Experimental learning: Demonstrate on thin film Fabrication by

Spray Pyrolysis **Applications:** Physical technique used for synthesis of nanoparticles **Video link / Additional online information:** 1. https://www.youtube.com/watch?v=HhGCNG2X8gQ 2. https://www.youtube.com/watch?v=Z51R49OOqAA		
Module-3	**RBT Level: L-1, L-2, L3**	**8 Hours**
Chemical methods: Chemical vapour deposition (CVD); plasma-enhanced CVD; low pressure plasma CVD; metalorganic CVD (MOCVD); photo-enhanced CVD; electron enhanced CVD; Laser induced CVD; atmospheric pressure CVD; reactive ion etching (RIE) molecular-beam epitaxy (MBE); chemical beam epitaxy (CBE); chemical bath deposition; electrochemical synthesis of nano structures. Sol- gel processing; fundamentals of sol-gel process; sol-gel synthesis methods for oxides; other inorganics and nano composites; the Pecheni method; silica gel; zirconia and Yttrium gel; aluminosilicate gel; polymer nano composites. Mechanochemistry: grinding and milling devices **Laboratory Sessions/ Experimental learning:** Synthesis of cadmium sulphide nanoparticles by Sol-Gel Method **Applications:** CVD processes widely use to deposit materials in various forms, including monocrystalline, polycrystalline, amorphous, and epitaxial. **Video link / Additional online information:** 1. https://www.youtube.com/watch?v=Z51R49OOqAA 2. https://www.youtube.com/watch?v=ULY7iprHlL		
Module-4	**RBT Level: L-1, L-2, L3**	**8 Hours**
Self-assembly: Bottom-up approach. Self-assembly; self-assembled mono layers; directed assembly; layer-by-layer assembly; spontaneous formation & ordering of nano structures; nano-fluidics to build silicon devices with features comparable in size to DNA, proteins & other biological molecules; Langmuir Blodgett films; electrochemical self-assembly of oxide/dye composites. Self-assembled nano biomaterials; pattern definition; pallsin transfer; atomic & molecular manipulation; biomineralization; colloidal quantum dots; self-assembly techniques **Laboratory Sessions/ Experimental learning:** Demonstrate the different self-assembly proceed **Applications:** Self-assembly of nanostructures is a process where atoms, molecules or nanoscale building blocks spontaneously organize into ordered structures or patterns		

with nanometer features without any human intervention. It is the most promising practical low-cost and high-throughput approach for nanofabrication

Video link / Additional online information:

https://www.youtube.com/watch?v=mad7Tasw75s.

https://www.youtube.com/watch?v=TgwpVGWL6dQ

https://www.youtube.com/watch?v=KXAEYdzG9U

Module-5	RBT Level: L-1, L-2, L3	8 Hours

LITHOGRAPHIC TECHNIQUES: Top-down approach to nanolithography; immersion lithography, EUV photolithography; phase shifting masks; x-ray lithography, including plasma x-ray sources; e-beam and focused ion-beam lithography; photo resist technologies for the nano scale; metrology and defect inspection. Soft lithography; nano imprint lithography; wet etching, dry etching (isotropic, anisotropic), pattern growth techniques (polymerization, directed assembly). Proximal probe nano lithography; STM; AFM; resists & imaging layers for proximal probes

Laboratory Sessions/ Experimental learning: Demonstrate on Circuit fabrication by Manual Lithography Techniques

Applications: Lithography can be used to print text or artwork onto paper or other suitable material. Lithography originally used an image drawn with oil, fat, or wax onto the surface of a smooth, level lithographic limestone plate.

Video link / Additional online information:

1. https://www.youtube.com/watch?v=nUXDltQfqSA
2. https://www.youtube.com/watch?v=nioYljr3oV8
3. https://www.youtube.com/watch?v=udXHWVejDj0

Course outcomes:

CO1	Understand the concept of the nano Fabrication method
CO2	Apply the knowledge of physical techniques for synthesis of nano structure
CO3	Apply the knowledge of Chemical techniques for synthesis of nano structure
CO4	Develop of the basic self-assembly and the different types of processing
CO5	Understand the lithographic Techniques

Text Books:

1	Nalwa, H. S. (2004). *Encyclopedia of nanoscience and nanotechnology. Volume 1, A-Ch*. American scientific publishers.

Reference Books:

1	Fahrner, W. R. (2005). *Nanotechnology and nanoelectronics*. Springer-Verlag

	New York Incorporated.
2	Frank, J. Owens and Charles, P. Poole (2003). *Introduction to Nanotechnology*. Wiley-IEEE.

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes – 2 Nos.		2*2=4
Activities/ Experimentations related to course/ Seminar presentation – 2 Nos.		2*5=10
Mini Projects/ Case studies/Assignments – 3 Nos.		3*2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	--	--	--	--	1	--	--	--	--	--
CO2	3	2	1	--	--	1	1	--	--	--	--	--
CO3	3	2	1	--	--	1	1	--	--	--	--	--
CO4	3	2	1	--	--	1	1	--	--	--	--	--
CO5	3	2	1	--	--	1	1	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	COMPUTATIONAL FLUID DYNAMICS	Semester	VII
Course Code	MVJ20CH741	**CIE**	50
Total No. of Contact Hours	40 L : T : P :: 20: 0: 20	**SEE**	50
No. of Contact Hours/week	4	**Total**	100
Credits	3	**Exam. Duration**	3 Hours

Course objective is to:

- To introduce Governing Equations of viscous fluid flows
- To introduce numerical modeling and its role in the field of fluid flow and heat transfer
- To enable the students to understand the various discretization methods, solution procedures and turbulence modeling.
- To create confidence to solve complex problems in the field of fluid flow and heat transfer by using high speed computers.

Module-1	**RBT Level: L1, L2, L3**	**8 Hours**

Introduction: Illustration of the CFD approach, CFD as an engineering analysis tool, Review of governing equations, Modelling in engineering, Partial differential equations- Parabolic, Hyperbolic and Elliptic equation, CFD application in Chemical Engineering, CFD software packages and tools.

Experiential learning: Demonstrate the CFD software packages and tools.

Application: Computational Fluid Dynamics (CFD) involves the numerical solution of conservation equations for mass, momentum and energy in a flow geometry and used in different domain of chemical engineering like fluid dynamics, heat transfer, reaction engineering and mass transfer.

Video link / Additional online information:

https://www.youtube.com/watch?v=4bcInyoawHY&list=PLbRMhDVUMngcFmWiK1YBhAbsYo8mYvPKJ&index=2

https://nptel.ac.in/courses/112/107/112107080/

https://onlinecourses.nptel.ac.in/noc20_me64/preview

Module-2	**RBT Level: L1, L2, L3**	**8 Hours**

Finite difference and finite volume methods: Derivation of finite difference equations – Simple Methods – General Methods for first and second order accuracy – Finite volume formulation for steady state One, Two and Three -dimensional diffusion problems –

Parabolic equations – Explicit and Implicit schemes – Example problems on elliptic and parabolic equations – Use of Finite Difference and Finite Volume methods **Experiential Learning:** Demonstrate the different applications of finite difference and finite volume methods with some example. **Application:** Finite Difference Method: It is difficult to satisfy conservation and to apply for irregular geometries Finite Volume Method: It tends to be biased toward edges and one-dimensional physics. **Video Links/Any other special information:** NPTEL: https://www.youtube.com/watch?v=vf0S_1ZITuA https://onlinecourses.nptel.ac.in/noc20_me82/preview https://www.youtube.com/watch?v=_yNhPstPBOY https://www.youtube.com/watch?v=WwgrAH-IMOk		
Module-3	**RBT Level: L1, L2, L3**	**8 Hours**
Solution algorithms: Steady one-dimensional convection and diffusion – Central, upwind differencing schemes properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Hybrid, Power-law, QUICK Schemes. **Experiential Learning:** Use Finite Difference and Finite Volume Methods in CFD Modelling **Application:** Central Upwind Scheme used for Solving Special Relativistic Hydrodynamic Equations **Video Links/Any other special information:** 1.https://www.youtube.com/watch?v=A-GCsFw68jw 2. https://www.youtube.com/watch?v=-kfKaxWf0JY 3.https://www.youtube.com/watch?v=wVgIJDrMpdQ		
Module-4	**RBT Level: L1, L2, L3**	**8 Hours**
Flow field analysis: Finite volume methods -Representation of the pressure gradient term and continuity equation – Staggered grid – Momentum equations – Pressure and Velocity corrections – Pressure Correction equation, SIMPLE algorithm and its variants – PISO Algorithms. **Experiential Learning:** Demonstrate the steps in SIMPLE Algorithm. **Application:** In computational fluid dynamics (CFD), the SIMPLE algorithm is a widely used numerical procedure to solve the Navier–Stokes equations. **Video Links/Any other special information:** https://www.youtube.com/watch?v=DYTg71UACfI https://www.youtube.com/watch?v=ambbGRqMeJU		

https://www.youtube.com/watch?v=KR74TQesUoQ

https://nptel.ac.in/courses/112/105/112105254/

Module-5	RBT Level: L1, L2, L3	8 Hours

Turbulence models, mixing length model, Two equation (k-ε) models – High and low Reynolds number models – Structured Grid generation – Unstructured Grid generation – Mesh refinement – Adaptive mesh – Software tools

Experiential Learning: Tutorial on Mesh Generation on Different Geometries with increasing complexities.

Application: Applications in Fluid Mechanics, Heat Transfer related problems in Chemical Engineering

Video Links/Any other special information:

https://www.youtube.com/watch?v=nOLsa9WnhlU

https://www.youtube.com/watch?v=zs-sDuoeTVA

https://www.youtube.com/watch?v=yGUg3WV3QLE

https://nptel.ac.in/courses/112/105/112105254/

Course outcomes:

CO1	Understand the concept of computational fluid dynamics and its application
CO2	Analyze the consistency, stability and convergence of various discretization schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO3	Apply finite difference and finite volume methods to various chemical engineering problems.
CO4	Analyze variations of SIMPLE schemes for incompressible flows and variations of Flux Splitting algorithms for compressible flows.
CO5	Evaluate the grid sensitivity and analyse the accuracy of a numerical solution.

Text Books:

1	Versteeg, H. K., &Malalasekera, W. (2007). *An introduction to computational fluid dynamics: the finite volume method*. Pearson education.
2	Muralidhar, K. and Sundararajan (Narosa), T. (2011). Computational Fluid Flow and Heat Transfer 2nd Edition.

Reference Books:

1	Patankar, S.V. (2004). Numerical Heat Transfer and Fluid Flow. (Hemisphere

	Publishing Corporation).
2	Chung, T. J. (2002). *Computational fluid dynamics*. Cambridge university press.

Scheme of Evaluation:

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Assignments (2 Nos.)		5X2=10
Journals/Progress notes		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	--	--	2	--	--	--	--	--	--	--
CO2	3	3	--	--	2	--	--	--	--	--	--	--
CO3	3	3	2	--	2	--	--	--	--	--	--	--
CO4	3	3	2	--	2	--	--	--	--	--	--	--
CO5	3	3	--	--	2	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	PROCESS ENGINEERING ECONOMICS	Semester	VII
Course Code	MVJ20CH742	CIE	50
Total No. of Contact Hours	40 L : T : P ::20:20:0	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

To study various phases in process design & development.

To determine cost involved in various processes.

Estimation of capital cost, alternative investments and replacement analysis.

To study direct, indirect expenses involved and profitability evaluation methods.

To study various financial statements, significance of financial ratios and cash flow diagram.

Module-1	RBT Level: L1, L2, L3	8 Hours

Process design development: Overall planning of a plant, Feasibility studies and Material & energy balance, Equipment sizing and selection, Analysis of Process flow sheet, P & I diagram, Plant layout and location, Factors affecting plant design.

Experiential Learning: Demonstrating P&ID, Plant location and its feasibility.

Applications: Factors to be considered for plant selection and location.

Video link / Additional online information:

https://www.youtube.com/watch?v=BzPTGWKLP7c

https://www.youtube.com/watch?v=8PZrEkTUqDI

Module-2	RBT Level: L1, L2, L3	8 Hours

Cost analysis: Elements of project cost - cost information, Factors affecting investment & production cost, Estimation of capital investment, operation costs, project financing, Factors in capital investment, Estimation of working capital, cost index, taxes and insurance. **Time value of money**: Types of interests, Effective and nominal interest rates, present worth and discount.

Experiential Learning: Comparing different types of costs and their impact.

Applications: Able to understand the sequence of cost flow in any industry.

Finite Volume Method: It tends to be biased toward edges and one-dimensional physics.

Video Links/Any other special information:

https://www.youtube.com/watch?v=65PlvATnK1o

https://www.youtube.com/watch?v=nutIE5uGi5c&list=PLbMVogVj5nJS8aivkHJC_5KMvYj7wMcvk&index=32

Module-3	RBT Level: L1, L2, L3	8 Hours

Depreciation & taxes: Types of Depreciation and calculation methods. **Profitability:** Profitability, Cash flow diagrams, break even analysis, measures of process profitability, methods of evaluation of profitability - Rate of return on investment, Discounted cash flow based on full-life performance, Net present worth, Capitalized costs, Payout period, Simplified model for economic analysis of process design.

Experiential Learning: Case study on economic analysis of a process design.

Applications: Detailed techno-economic analysis of any chemical process.

Video Links/Any other special information:

1 https://www.youtube.com/watch?v=1tOrhhjVjH0

https://www.youtube.com/watch?v=nutIE5uGi5c&list=PLbMVogVj5nJS8aivkHJC_5KMvYj7wMcvk&index=32

Module-4	RBT Level: L1, L2, L3	8 Hours

Replacements: Theory of replacements, causes for replacements types of replacements. **Alternative investments:** Theory of alternative investments and causes for the same. **Optimum design and design strategy:** Procedures for determining optimum conditions- Single and multi-variable procedures, Significance of breakeven chart for optimum analysis, Optimum rate of production- concept of minimum cost of the product, maximum cost of the product and case of maximum profit

Experiential Learning:: Case study on optimum conditions determination using any tool.

Applications: The application of optimum design and its strategy for process industries.

Video Links/Any other special information:

https://www.youtube.com/watch?v=wW9mejsHLvg

https://www.youtube.com/watch?v=nutIE5uGi5c&list=PLbMVogVj5nJS8aivkHJC_5KMvYj7wMcvk&index=32

Module-5	RBT Level: L1, L2, L3	8 Hours

Financial statements: Introduction to financial statements, Cash flow diagrams, balance sheet and Break-even analysis.

Equipment cost and design report: Heat transfer equipment costs, Mass transfer equipment costs, Plate and packet towers, dryers, cost estimation for reactor equipment components, cost of piping.

Design report: Introduction to design of reports. Types of reports, Organization of report and purpose of report.

Experiential Learning: Cost-estimation of any simple chemical equipment.

Applications: Estimating the best cost with economic considerations for chemical process industries. **Video Links/Any other special information:** https://www.youtube.com/watch?v=80vu5lxOluQ https://www.youtube.com/watch?v=Om24w_EcWlE	
Course outcomes:	
CO1	Discuss basic aspects of process development and economics, process flow sheet.
CO2	Explain the concepts of elements of project costing and time value of money.
CO3	Calculate various cost elements and draw cash flow diagrams and economic analysis of process design.
CO4	Explain theory of replacements and alternative investments and determine optimum cost and rate of product.
CO5	Discuss financial statements, breakeven analysis and prepare design reports, and determine equipment and piping costs.
Text Books:	
1	Banga, T.R. and Sharma, S.C. (1999). Industrial Organization & Engineering Economics 22nd Edition. (Khanna Publishers).
2	Peters, M. S., Timmerhaus, K. D., & West, R. E. (2003). *Plant design and economics for chemical engineers* (Vol. 4). New York: McGraw-Hill.
Reference Books:	
1	Happel, J. and Jordan, D.J. Chemical Process Economics. (Marcal Dekker Inc.) ISBN: 0824761553, 2005.
2	Web Link and Video Lectures: https://nptel.ac.in/courses/103103039/

Scheme of Evaluation:

Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Assignments (2 Nos.)		5X2=10
Mini project/Case studies		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	--	--	--	--	--	--	--	--	--
CO2	3	3	3	--	--	--	--	--	--	--	--	--
CO3	3	3	3	--	--	--	--	--	--	--	--	--
CO4	3	3	3	--	--	--	--	--	--	--	--	--
CO5	3	3	3	--	--	--	--	--	--	2	2	2

High-3, Medium-2, Low-1

Course Title	PROCESS INTENSIFICATION	Semester	VI
Course Code	MVJ20CH743	CIE	50
Total No. of Contact Hours	40 L: T: P:: 20 : 10 : 10	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- To provide an understanding of the concept of Process Intensification.
- To provide knowledge and understanding of application of intensification techniques to a range of processes e.g. heat and mass transfer, separation processes.
- To understand the scientific background, techniques and applications of intensification in the process industries

Module-1	RBT Level: L1, L2, L3	8 Hours

Introduction: Theory of Process Intensification, Process Intensification (PI) Applications, Main benefits from process intensification, Process-Intensifying equipment, Process intensification toolbox, Techniques for PI application.

Experiential Learning: Debottlenecking in the chemical process industries

Applications: Students will understand how to reduce the generation of wastewater in the chemical process industries

Video Links/Any other special information (Papers):

https://nptel.ac.in/courses/103/103/103103152/

Module-2	RBT Level: L1, L2, L3	8 Hours

Process intensification through micro reaction technology: Effect of miniaturization on unit operations and reactions, Design rules, Implementation of Micro reaction Technology, Micro fabrication of reaction and unit operation devices - Scales of mixing Flow patterns in reactors, Mixing in stirred tanks: Scale up of mixing, Heat transfer. Mixing in intensified equipment, Atomizer, Nebulizers

Experiential Learning: Demonstration on Micro Reactor

Applications: Students will be able to understand the importance of Micro reactor which evolved from a highly advanced toy for chemical engineers to a versatile tool for chemical synthesis

Video Links/Any other special information (Papers):

https://nptel.ac.in/courses/103/103/103103152/

Module-3	RBT Level: L1, L2, L3	8 Hours

Combined chemical reactor heat exchangers and reactor separators: Principles of operation; Applications, Reactive absorption, Reactive distillation, Applications of RD Processes, Fundamentals of Process Modelling, Reactive Extraction Case Studies: Absorption of NOx Coke Gas Purification.

Experiential Learning: Demonstration on Chemical reactor heat exchangers

Applications: Students will be able to understand the importance of chemical reactor heat exchanger, most chemical reactions are faster at higher temperatures and heat exchangers are frequently used to provide the heat necessary to increase the temperature of the reaction.

Video Links/Any other special information (Papers):

https://nptel.ac.in/content/storage2/courses/103103029/pdf/mod1.pdf

Module-4	RBT Level: L1, L2, L3	8 Hours

Compact heat exchangers: Classification of compact heat exchangers, Plate heat exchangers, Spiral heat exchangers, Flow pattern, Heat transfer and pressure drop, Flat tube-and-fin heat exchangers, Micro channel heat exchangers, Phase-change heat transfer, Selection of heat exchanger technology, Feed/effluent heat exchangers, Integrated heat exchangers in separation processes.

Experiential Learning: Demonstration on Spiral heat exchanger

Applications: Students will be able to understand the various industrial process applications of spiral heat exchanger because they can perform tasks such as: pasteurization, digester heating, heat recovery, pre-heating and effluent cooling.

Video Links/Any other special information (Papers):

https://nptel.ac.in/noc/courses/noc18/SEM2/noc18-me43/

Module-5	RBT Level: L1, L2, L3	8 Hours

Enhanced fields: Energy based intensifications, Sono-chemistry, Basics of cavitation, Cavitation reactors, Nusselt flow model and mass transfer, The Rotating electrolytic Cell, Electrostatic fields, Sono crystallization, Supercritical fluids.

Experiential Learning: Demonstration on Sonocrystallization.

Applications: Students can understand the modern technique which involves the application of ultrasound energy to control the nucleation and crystal growth of a crystallization process.

Video Links/Any other special information (Papers):

https://nptel.ac.in/content/storage2/courses/103105060/Sde_pdf/Module-10.pdf

Course outcomes:

CO1	Explain the concept of Process Intensification and the methodologies for PI.
CO2	Explain the benefits of PI in the process industries.
CO3	Explain the operating principles of a number of intensified technologies.
CO4	Analyse the range of potential applications of intensified equipment.
CO5	Solve process challenges using intensification technologies
Text Books:	
1	Reay, D. (2005). Re-Engineering the Chemical Processing Plant: Process Intensification, Andrzej Stankiewicz, Jacob A. Moulijn (Eds.), Marcel Dekker, Inc (2003), p. 529, $165, ISBN: 0 8247 4302 4.
2	Stankiewicz, A., Van Gerven, T., &Stefanidis, G. (2019). The fundamentals of process intensification. John Wiley & Sons.
Reference Books:	
1	Reay, D., Ramshaw, C., & Harvey, A. (2013). Process Intensification: Engineering for efficiency, sustainability and flexibility. Butterworth-Heinemann.
2	Boodhoo, K., & Harvey, A. (Eds.). (2013). Process intensification technologies for green chemistry: engineering solutions for sustainable chemical processing. John Wiley & Sons.

Scheme of Evaluation		
Details		**Marks**
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	**CIE (50)**	**30**
Quizzes - 2Nos.		**2X2=4**
Activities/ Experimentations related to course (1 in each module)		**5X2=10**
Assignments / Discussion of Journal papers - 3Nos.		**3X2=6**
Semester End Examination	**SEE (50)**	**50**
	Total	**100**

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	--	--	--	--	--	--	--	--	--	--	--
CO2	3	2	2	--	--	2	2	--	--	--	2	3
CO3	3	2	2	--	--	2	2	--	--	--	2	3
CO4	3	2	2	--	--	2	2	--	--	--	2	3
CO5	3	2	--	--	--	2	2	--	--	--	2	3

High-3, Medium-2, Low-1

Course Title	MULTI-COMPONENT DISTILLATION	Semester	VII
Course Code	MVJ20CH744	CIE	50
Total No. of Contact Hours	40 L: T: P:: 20 : 10 : 10	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to: • Understand the concept of distillation applicable to multi-component systems. • Calculate parameters for multicomponent distillation • Be able to optimize process conditions. • Design multicomponent distillation systems		
Module-1	**RBT Level: L1, L2, L3**	**8 Hours**
Introduction: Multi component distillation. Thermodynamic relationships for multi component mixture, prediction of phase equilibrium. **Phase Equilibria**: Use of fugacities and activities. Introduction to the method of convergence characteristics. The Theta method for converging temperature. Profile-Development & application to conventional distillation columns. The 2N Newton-Raphson method- Introduction and the Algorithm. The method of successive approximations **Experiential Learning**: Demonstrate how to establish the correlation between thermodynamics and phase equilibria **Applications**: Phase equilibria is the co-existence of various phases as a function of variables, formed in multicomponent systems is governed by the law of heterogeneous thermodynamics. **Video Links/Any other special information (Papers):** https://www.youtube.com/watch?v=oFwTlyu9-9o https://www.youtube.com/watch?v=m-7GSTNei-M https://www.tms.org/pubs/journals/JOM/9712/Kattner-9712.html		
Module-2	**RBT Level: L1, L2, L3**	**8 Hours**
Multicomponent Distillation: Azeotropic and extractive distillation process qualitative & quantitative estimations characteristics and applications. **Phase Behaviour at Constant Pressure:** Homogeneous and heterogeneous azeotropes. **Experiential Learning**: Demonstration of separation process of components having close boiling		

points (Azeotropic mixture).

Applications: To separate a multicomponent mixture with n components into n pure products through distillation, a sequence of distillation columns referred to as a distillation configuration is usually required.

Video Links/Any other special information (Papers):

https://www.osti.gov/servlets/purl/1433494

https://link.springer.com/article/10.1007%2Fs11814-007-0002-1

https://aiche.onlinelibrary.wiley.com/doi/abs/10.1002/aic.690340411

Module-3	RBT Level: L1, L2, L3	8 Hours

Thermodynamic Property Evaluation: Fundamental principles involved in the separation of multi component mixtures – Determination of bubble-point and Dew Point Temperatures for multi component mixtures – equilibrium flash distillation calculations for multi component mixtures – separation of multi component mixtures at total reflux.

Experiential Learning: Demonstration of multiphase reactor which aims at improving chemical reaction by simultaneous product removal and evaluation of thermodynamic properties.

Applications: There are various reactions that satisfy this criterion, but this technology is applied only for etherification, esterification, and alkylation (synthesis of ethylbenzene or cumene) on an industrial scale.

Video Links/Any other special information (Papers):

https://www.nist.gov/publications/critical-evaluation-thermodynamic-properties-halobenzoic-acids-through-consistency

Module-4	RBT Level: L1, L2, L3	8 Hours

Minimum Reflux Ratio for MCD System: General considerations in the design of columns – Column sequencing – Heuristics for column sequencing – Key components – Distributed components – Non-Distributed components -Adjacent keys. Definition of minimum reflux ratio – calculation of Rm for multi component distillation – Underwood method – Colburn method.

Experiential Learning: Studies on Evaluation of Optimum Reflux ratio using Underwood method.

Applications: Number of numerical methods have been developed. One of the most powerful techniques is the Underwood method and Colburn method to evaluate minimum and optimum reflux ratio for Multi component systems.

Video Links/Any other special information (Papers):

https://cheguide.com/shortcut_distillation.html

Module-5	RBT Level: L1, L2, L3	8 Hours

Various Types of MCD Columns: Design of sieve, bubble cap, valve trays and structured packing columns for multi component distillation – computation of plate efficiencies.

Experiential Learning: Demonstration of various types of trays and packing materials used for designing Multi component distillation columns.

Applications: Helps to understand how to calculate the plate efficiencies and also design parameters for multi component and applications in petroleum refineries, petrochemical and chemical plants and natural gas processing plants.

Video Links/Any other special information (Papers):

https://aiche.onlinelibrary.wiley.com/doi/abs/10.1002/aic.690170520#:~:text=In%20the%20design%20of

%20the,the%20liquid%20leaving%20the%20plate

https://nitsri.ac.in/Department/Chemical%20Engineering/Distillation_Notes-PartIV.pdf

http://facstaff.cbu.edu/rprice/lectures/distill6.html

Course outcomes:

CO1	Explain the concept of Phase equilibria in Multi component systems and its principles
CO2	Explain the various distillation processes and Phase behavior at constant pressure
CO3	Explain the evaluation of thermodynamic properties for multi component distillation.
CO4	Apply numerical methods for determining the minimum reflux ratio for MCD Systems.
CO5	Explain the various types of MCD Columns.

Text Books:

1	Holland, C. D. (1981). Fundamentals of multicomponent distillation (Vol. 543). New York: McGraw-Hill.
2	Billet, R. (1979). Distillation engineering.

Reference Books:

1	King, C. J. (2013). Separation processes. Courier Corporation.
2	Holland, C. D. (1966). Unsteady State Processes with Applications in Multicomponent Distillation. Prentice-Hall.

Scheme of Evaluation		
Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., $\sum$ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Activities/ Experimentations related to course (1 in each module)		5X2=10
Assignments / Discussion of Journal papers - 3Nos.		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	--	--	--	--	--	--	--	--	--	--
CO2	3	2	--	--	--	--	--	--	--	--	--	--
CO3	3	--	--	--	--	--	--	--	--	--	--	--
CO4	3	2	--	--	--	--	--	--	--	--	--	--
CO5	3	2	--	--	--	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	GREEN TECHNOLOGY	Semester	VII
Course Code	MVJ20CH751	CIE	50
Total No. of Contact Hours	40 L : T : P :: 40 : 0 : 0	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- Learn the tools of green technology
- Know various forms of renewable energy
- Study the environmental consequences of energy conversation
- Understand energy audits and residential energy audit
- Understand the application of green technology in various industries

Module-1	RBT Level: L1, L2	8 Hours

Current Practices and Future Sustainability: Need for green technology, fundamentals of energy and its impact on society and the environment, the mechanics, advantages and disadvantages of renewable energy sources, energy conservation and audits, zero waste technology, life cycle assessment, extended product responsibility, concept of atom economy, tools of Green technology

Cleaner Production: Promoting cleaner production, benefits and obstacles of cleaner production, cleaner production technologies

Experiential Learning: Green Synthesis of Nano particles using Plants can be demonstrated in the laboratories.

Applications: The main purpose of green technology is to slow down global warming and reduce the greenhouse effect. The main idea is the creation of new technologies which do not damage the natural resources.

Video Links:https://nptel.ac.in/courses/103107157/

https://nptel.ac.in/courses/121/106/121106014

Module-2	RBT Level: L1, L2	8 Hours

Solar Radiation and Its Measurement: Solar constant, solar radiation at the earth's surface, solar radiation geometry, solar radiation measurements Applications of Solar Energy: Introduction, solar water heating, space-heating (or solar heating of buildings), space cooling (or solar cooling of building), solar thermal electric conversion, agriculture and industrial process heat, solar distillation, solar pumping, solar cooking Geothermal Energy: Resource identification and development, geothermal power generation systems, geothermal power plants case studies and environmental impact assessment.

Experiential Learning: Demonstration to Learn how to assess the solar energy potential of a site using a pyranometer.

Demonstration on working of Solar Water Heater.

Applications: Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. solar radiation measurements are of primary interest for applications like site-specific solar resource assessments, PV performance evaluation, solar resource forecasting, and so on.

Video Links:https://www.energy.gov/eere/solar/solar-radiation-basics

https://www.hukseflux.com/applications/solar-energy-pv-system-performance-monitoring/how-to-measure-solar-radiation

Module-3	RBT Level: L1, L2	8 Hours

Energy from biomass (bio-energy): Introduction, biomass conversion technologies, wet Processes, dry Processes, biogas generation, factors affecting bio digestion, types of biogas plants (KVIC model & Janata model), selection of site for biogas plant Bio Energy (Thermal Conversion): Methods for obtaining energy from biomass, thermal gasification of biomass, classification of biomass gasifiers, chemistry of the gasification process, applications of the gasifiers.

Experiential Learning: Demonstration of an experiment to produce biogas from various sources of biomass using Bio methanation.

Applications: Biomass is renewable organic material that comes from plants and animals. Biomass contains stored chemical energy from the sun. Biomass can be burned directly for heat or converted to renewable liquid and gaseous fuels through various processes

Video Links:https://www.ovoenergy.com/guides/energy-sources/bio-fuels.html

https://www.nrel.gov/research/re-biomass.html

Module-4	RBT Level: L1, L2	8 Hours

Wind Energy: Introduction, basic components of WECS (Wind Energy Conversion system), classification of WEC systems, types of wind machines (Wind Energy Collectors), horizontal-axial machines and vertical axis machines. Ocean Thermal Energy:

OTEC-Introduction, ocean thermal electric conversion (OTEC), methods of ocean thermal electric power generation, open cycle OTEC system, the closed or Anderson, OTEC cycle,

Hybrid cycle Energy from Tides: Basic principles of tidal power, components of tidal power plants, operation methods of utilization of tidal energy, advantages and limitations of tidal power generation

Experiential Learning: Demonstration of wind turbines and case studies on Wind energy. **Applications:**OTEC is potentially capable to produce more energy than conventional tidal, wave, and wind energy combined. The OTEC technologies, in principle, is to turn warm surface water into steam, or used to heat another fluid into vapour and spins a turbine to produce electricity. **Video Links:** www.emsd.gov.hk/energyland/en/energy/renewable/otec.html#:~:text=It%20is%20believed%20that%20OTEC,a%20turbine%20to%20produce%20electricity. http://otecokinawa.com/en/OTEC/index.html

Module-5	RBT Level: L1, L2	8 Hours
Hydrogen as a Fuel: Introduction, methods of hydrogen production (principles only), storage transportation, utilization of hydrogen gas, hydrogen as alternative fuel for motor vehicle, safety and management, hydrogen technology development in India. **Application of Green Technology:** Electronic waste management, bioprocesses, green composite materials, green construction technology Sustainability of industrial waste management: Case studies on cement industry, iron and steel industry, petroleum sectors, marble and granite industry, sugar industry **Experiential Learning:**Demonstrate an experiment for production of hydrogen by downward displacement setup as a project in laboratory. **Applications:** The use of hydrogen greatly reduces pollution. When hydrogen is combined with oxygen in a fuel cell, energy in the form of electricity is produced. This electricity can be used to power vehicles, as a heat source and for many other uses. **Video Links:** https://www.cesa.org/wp-content/uploads/CESA-Lipman-H2-prod-storage-050311.pdf https://en.wikipedia.org/wiki/Hydrogen_production		

Course outcomes:

CO1	Recall the fundamentals of various forms of energy
CO2	Explain the principles of various forms of renewable energy
CO3	Apply the concept of zero waste, atom economy for waste management
CO4	Create a waste management plan incorporating tools of green technology in various industries
CO5	Explain the various methods for Hydrogen production, storage, transportation and utilization.

Text Books:	
1	Rai, G. D. (2004). Non-conventional energy resources. *Khpu Khanna, India, 369*, 331-337.
2	Twidell, J., & Weir, T. (2015). *Renewable energy resources*. Routledge.
Reference Books:	
1	Boyle, G. (1996). *Renewable energy: power for a sustainable future* (Vol. 2). Oxford University Press.
2	Everett, R., Boyle, G., Peake, S., & Ramage, J. (2012). *Energy systems and sustainability: power for a sustainable future*. Oxford Univerity Press.

Scheme of Evaluation:		
Details		**Marks**
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Activities/ Experimentations related to course (1 in each module)		5X2=10
Mini Projects/ Case studies- 2 Nos.		3X2=6
Semester End Examination	SEE (50)	50
Total		**100**

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	--	--	--	1	2	1	--	1	--	--
CO2	2	1	--	--	--	1	2	--	--	--	--	--
CO3	1	2	1	2	1	3	3	3	2	1	1	--
CO4	2	1	2	2	--	--	2	--	--	1	3	--
CO5	2	1	--	--	--	1	2	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	AIR POLLUTION AND CONTROL	Semester	VII
Course Code	MVJ20CH752	CIE	50
Total No. of Contact Hours	40 L : T : P :: 40 : 0 : 0	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- Understand knowledge on the principles and design of control of indoor/ particulate / gaseous air pollutant and its emerging trends.

Module-1	RBT Level: L1, L2, L3	8 Hours

INTRODUCTION: Structure and composition of Atmosphere – History of Air pollution and episodes, Causes of air pollution and types, Introduction to meteorology toxicology and transport of air pollution, Sources and classification of air pollutants - Effects of air pollutants on human health, vegetation & animals, Materials & Structures – Effects of air Pollutants on the atmosphere, Soil & Water bodies – Long- term effects on the planet – Global Climate Change, Ozone Holes – Ambient Air Quality and Emission Standards – Air Pollution Indices – Emission Inventories.

Experiential Learning: Demonstrate the importance of controlling air pollution and emission standard.

Applications: Air quality can be measured based on the emission standard in different locations.

Video Links:

NPTEL: https://www.youtube.com/watch?v=XHy1eqJqzKk

NPTEL WEB CONTENT: https://nptel.ac.in/courses/105/102/105102089/

MIT LECTURE NOTE: https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-335-experimental-atmospheric-chemistry-fall-2014/lecture-notes/

Module-2	RBT Level: L1, L2, L3	8 Hours

AIR POLLUTION MONITORING AND MODELING: Physicochemical processes governing the spread of pollutants from point, non-point, line, and area sources; Generation, transport and decay of air pollutants; Mathematical Modelling of dynamics of pollutants, Ambient and Stack Sampling and Analysis of Particulate and Gaseous Pollutants - Effects of meteorology on Air Pollution - Fundamentals, Atmospheric stability, Inversion, Wind profiles and stack plume patterns- Transport & Dispersion of Air

Pollutants – Modelling Techniques – Air Sampling and monitoring methods.

Experiential Learning: Demonstrate the modelling technique and air sampling methods.

Applications: Dispersion of air pollutant from chimney, in the air can be measured by wind profile and stack plume patterns.

Video Links:

NPTEL WEB CONTENT: https://nptel.ac.in/courses/105/102/105102089/

NPTEL COURSE: https://onlinecourses.nptel.ac.in/noc20_ch01/preview

https://nptel.ac.in/courses/105/104/105104099/

https://www.youtube.com/watch?v=9uqQ6xaETZg

Module-3	RBT Level: L1, L2, L3	8 Hours

CONTROL OF PARTICULATE CONTAMINANTS: Factors affecting Selection of Control Equipment - Gas Particle Interaction, Working principle, Design and performance equations of Gravity Separators, cyclones, Fabric filters, Particulate Scrubbers, Electrostatic Precipitators - Operational Considerations -Process Control and Monitoring - Costing of APC equipment - Case studies for stationary and mobile sources.

Experiential Learning: Demonstrate different device available for controlling particulate matter.

Applications: Gravity Separators, cyclones, Fabric filters, Particulate Scrubbers, Electrostatic Precipitators are used for controlling particulate matter in industry.

Video Links:

https://nptel.ac.in/courses/105/104/105104099/

https://www.youtube.com/watch?v=5hKjurPjzwI

Module-4	RBT Level: L1, L2, L3	8 Hours

CONTROL OF GASEOUS CONTAMINANTS: Control Equipment, Factors affecting Selection of Control Equipment - Working principle, Design operation and performance of absorption, Adsorption, condensation, Incineration, Bio scrubbers, Bio filters - Process control and Monitoring - Operational Considerations -Costing of APC Equipment - Case studies for stationary and mobile sources.

Experiential Learning: Demonstrate different device available for controlling gaseous contaminant.

Applications: Adsorption, condensation, Incineration, Bio scrubbers, Bio filters are implemented in the industries for controlling gaseous pollutant.

Video Links:

https://nptel.ac.in/courses/105/104/105104099/

https://www.youtube.com/watch?v=sR0U9h_kMTw https://www.youtube.com/watch?v=sw_GjLZ89aY

Module-5	RBT Level: L1, L2, L3	8 Hours
AUTOMOBILE AND NOISE POLLUTION: Vehicular Pollution: Automobile emission - Types of emissions - Exhaust emissions, evaporative emissions, crank-case emissions- Prevention and control of vehicular pollution. Noise Pollution: Sources and Effects of Noise Pollution - Measurement - Standards - Control and Preventive measures. Sources types and control of indoor air pollutants, sick building syndrome types - Radon Pollution and its control. Air pollution legislation and regulations. Case studies of a few industrial pollution control systems. **Experiential Learning:** Demonstrate the important of controlling automobile and noise pollution. **Applications:** Air pollution legislation and regulation should be strictly followed to control the air pollution. **Video Links:** 1. https://www.youtube.com/watch?v=tsvBXUQWAOU 2. https://www.youtube.com/watch?v=LyaVQBfVq7w 3. https://nptel.ac.in/courses/103/107/103107084/		

Course outcomes:	
CO1	Explain the fundamentals of Atmospheric pollution and discuss the effects of Process Air Pollution.
CO2	Discuss Air pollution monitoring and Mathematical modeling of dynamics of pollutants.
CO3	Explain the control of particulate contaminants
CO4	Explain the control of gaseous contaminants
CO5	Discuss the automobile and noise pollution and the types of automobile emissions

Text Books:	
1	Wang, L. K., Pereira, N. C., & Hung, Y. T. (Eds.). (2004). *Air pollution control engineering* (Vol. 1, pp. 157-165). Totowa, NJ: Humana press.
2	De Nevers, N. (2010). *Air pollution control engineering*. Waveland press.
Reference Books:	

1	David, H.F. Liu, Bela G. Liptak. (2000).*Air Pollution*, Lewis Publishers.
2	Anjaneyulu, Y. (2002).*Air Pollution & Control Technologies,* Allied Publishers (P) Ltd. India.
3	Vallero, D. (2014). *Fundamentals of air pollution*. Academic press.

Details		**Marks**
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	**CIE (50)**	**30**
Quizzes - 2 Nos.		**2X2=4**
Activities/ Experimentations related to course/ Assignment -2 Nos. /Presentation - 1 Nos		**3X2=6**
Mini Projects/ Case studies/ Journal Report - 2 Nos.		**2X5=10**
Semester End Examination	**SEE (50)**	**50**
Total		**100**

CO-PO Mapping												
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	2	--	--	--	--	3	3	3	--	--	--	--
CO2	2	2	--	--	--	3	3	3	--	--	--	--
CO3	2	2	--	--	--	3	3	3	--	--	--	--
CO4	3	2	--	--	--	3	3	3	--	--	--	--
CO5	2	--	--	--	--	3	3	3	--	--	--	--

Course Title	NANOSCIENCE & NANOTECHNOLOGY	Semester	VII
Course Code	MVJ20CH753	CIE	50
Total No. of Contact Hours	40 L : T : P :: 20 : 10 : 10	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	3	Exam. Duration	3 Hours

Course objective is to:

- Understand the behavior of various smart materials and its applications.
- Understand basics and synthesis of nano materials and their properties.
- Learn to analyze and assess parameters involved in synthesis and characterization.
- Understand the applications of nano technology in various fields.

Module-1	RBT Level: L1, L2	8 Hours

Introduction and scope -Introduction to nanoscale, History, Evolution of various disciplines towards nanoscale focus, Plethora of potential applications, Recent achievements in nanotechnology, short-term commercial commercially viable nanotechnology products, specific applications, challenges and opportunities, technology scope, areas and subdisciplines, commercialization scope, present course of investigation.

Experiential Learning: Demonstration of various Nanomaterials and its evolution towards discipline.

Applications: Nanomaterials finds vast applications in various fields. Helps to understand the history and evolution of nano scale and challenges and opportunities as well as scope in terms of technology.

Video Links/Any other special information (Papers):

https://nptel.ac.in/courses/118104008/

https://nptel.ac.in/courses/112104229/

Module-2	RBT Level: L1, L2	8 Hours

Basic nanotechnology science: Introduction, approach & scope, Key sub atomic particles, basic entities/particles of interest, basic physics terms of interest, scale of atomic entities, atomic distances and metaphors, elementary and non-elementary particles, key physical properties of elements, basic properties of silicon and basics of transistor operations: transistor, manufacturing approaches, manufacturing limitations

Experiential Learning: Synthesis of cadmium sulphide nanoparticles by Sol-Gel Method

Applications: Top down and bottom-up methods are used for synthesis of nano material.

Video Links/Any other special information (Papers):

https://www.youtube.com/watch?v=HhGCNG2X8gQ

https://www.youtube.com/watch?v=Z51R49OOqAA

https://www.youtube.com/watch?v=ULY7iprHlLw

Module-3	RBT Level: L1, L2	8 Hours

Nanomaterials: Synthesis and Characterization: Introduction, basic nanostructures: CNTs, nanowires, nanocones; quantum dots, quantum dot nanocrystals, ultra-nanocrystalline diamond, diamondoids, nanocomposites, thin films, nanofoams, nanoclusters, smart nanostructures.

Characterization of Nano materials: Microscopy-Scanning tunnelling microscope, atomic force microscope, scanning electron microscopy, Field Emission Scanning Electron Microscopy, transmission electron microscopy, Environmental Scanning Electron Microscopy (ESEM) High Resolution Transmission Electron Microscope (HRTEM), Surface enhanced Raman Spectroscopy, X-ray diffraction technique, X ray Photoelectron Spectroscopy Surface area analysis, particle size analysis, gravimetric analysis.

Experiential Learning: Demonstrate the different instruments used for characterization of mano material. Demonstrate the synthesis of Ceria Nanoparticles and Characterize using XRD and SEM analysis.

Applications: Understand various nano materials, synthesis methods. Characterization of prepared nanomaterial is required to determine the surface area, particle size and quantities based on its mass.

Video Links/Any other special information (Papers):

https://www.youtube.com/watch?v=lFYs3XDu4fQ

https://www.youtube.com/watch?v=iiT_KJJ1Uhs

https://www.ufe.cz/en/team/synthesis-and-characterization-nanomaterials

Module-4	RBT Level: L1, L2	8 Hours

Nanoscale Manufacturing: Nano manipulation, Nanolithography- Optical lithography, Photolithography, Dip pen nanolithography, Extreme UV Lithography, Electron beam (e-beam) lithography, Epitaxial Growth: classical growth modes, techniques for epitaxy: Liquid Phase Epitaxy (LPE), Physical Vapor Deposition (PVD),Molecular Beam Epitaxy (MBE). Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Self-Assembly

Experiential Learning: Circuit fabrication by Manual Lithography Techniques

Applications: Lithography can be used to print text or artwork onto paper or other suitable material. Lithography originally used an image drawn with oil, fat, or wax onto the surface of a smooth, level lithographic limestone plate.

Video Links/Any other special information(Papers):

https://www.youtube.com/watch?v=nUXDltQfqSA

https://www.youtube.com/watch?v=nioYljr3oV8

https://www.youtube.com/watch?v=udXHWVejDj0

Module-5	RBT Level: L1, L2	8 Hours

Application of Nanotechnology:Environment: remediation and mitigation using metal oxide nano particles, magnetic particles, Nanomembranes and nanofilters, Pollution prevention: nanocatalysis, environmental sensors Medicine and healthcare: diagnosis, biosensors, drug delivery, therapy Energy: Solar energy- Photovoltaics, Dye-sensitised solar cell, Quantum-dot- sensitized solar cells. Hydrogen energy-Hydrogen production and Hydrogen storage, hydrogen fuel cell, Energy Savings-Insulators and smart coatings, Energy- harvesting materials, Information and communication technologies: Integrated circuits, Data storage, Photonics, Displays, Information storage devices, Wireless sensing and communication.

Experiential Learning: Demonstrate the various application of nanotechnology in different sectors

Applications: Nanotechnology applied in various sector like remediation and mitigation of environmental pollution, medical and health care sector, hydrogen production etc.

Video Links/Any other special information(Papers):

https://nptel.ac.in/courses/118/102/118102003/

https://onlinecourses.nptel.ac.in/noc19_mm21/preview

Course outcomes:

CO1	Understand the concept of nano and its opportunities in various fields
CO2	Understand the basic science of basic nano technology
CO3	Identify various nano materials and recall nano materials synthesis,

	characterization techniques
CO4	Identify various nano manufacturing techniques.
CO5	Understand the applications of Nano technology in various fields.

Text Books:	
1	Varghese, P. I., & Pradeep, T. (2003). A textbook of nanoscience and nanotechnology. Tata McGraw-Hill Education.
2	Fiiipponi, L., & Sutherland, D. (Eds.). (2012). Nanotechnologies: principles, applications, implications and hands-on activities: A compendium for educators. European Union, Directorate General for Research and Innovation.
3	Bandyopadhyay. K. Nano Materials (2007). New Age International Publishers; First edition.
Reference Books:	
1	Callister, W. D. (2007). An introduction: material science and engineering. John Wiley and Sons Inc.
2	Hari, S.N. Nano-structured Materials and Nanotechnology, (2002), Gulf Professional Publishing, Academic Press.

Scheme of Evaluation		
Details		**Marks**
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes – 3 Nos.		3*2=6
Activities/ Experimentations related to course/ Seminar presentation – 2 Nos.		2*4=8
Mini Projects/ Case studies/Assignments – 3 Nos.		3*2=6
Semester End Examination	SEE (50)	50
Total		100

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	--	--	--	--	--	--	--	--	--	--
CO2	--	3	3	2	--	--	--	--	--	--	--	--
CO3	--	3	1	3	--	--	--	--	--	--	--	--
CO4	--	--	3	--	--	--	--	--	--	--	--	--
CO5	--	3	1	2	--	--	--	--	--	--	--	--

High-3, Medium-2, Low-1

Course Title	SOLID WASTE MANAGEMENT	Semester	VII
Course Code	MVJ20CH754	**CIE**	50
Total No. of Contact Hours	40 L : T : P :: 40 : 0 : 0	**SEE**	50
No. of Contact Hours/week	4	**Total**	100
Credits	3	**Exam. Duration**	3 hrs

Course objective is to:

- Understand solid waste management from an environmental public health perspective.
- Identify and discuss the public health, regulatory, planning, technical, and economic principles that influence the solid waste management system.

Module-1	RBT Levels: L1, L2, L3	8 Hours

INTRODUCTION: Definition, characteristics and perspectives of solid waste. Types of solid waste. Physical and chemical characteristics. Variation of composition and characteristics. Municipal, industrial, special and hazardous wastes.

General Aspects: Overview of material flow in society. Reduction in raw material usage. Reduction in solid waste generation. Reuse and material recovery. General effects on health and environment. Legislations.

Laboratory Sessions/ Experimental learning: Reduce, reuse and recycle lab waste

Applications: Students analyze about minimising the amount of waste we produce, reusing products as much as we can, and remembering to recycle any materials that can be used for a new purpose.

Video link / Additional online information:

https://nptel.ac.in/courses/120/108/120108005/

Module-2	RBT Levels: L1, L2, L3	8 Hours

ENGINEERED SYSTEMS: Typical generation rates. Estimation and factors affecting generation rates. On site handling. Storage and processing. Collection systems and devices. Transfer and transport.

Laboratory Sessions/ Experimental learning: Onsite Proper Solid Waste Handling Practices

Applications: Students analyze about minimising the amount of waste we produce, reusing products as much as we can, and remembering to recycle any materials that can be used for a new purpose and assess the onsite proper solid waste handling practices

Video link / Additional online information: https://nptel.ac.in/courses/105/103/105103205/		
Module-3	**RBT Levels: L1, L2, L3**	**8 Hours**
PROCESSING TECHNIQUES: Mechanical volume reduction. Thermal volume reduction. Component separation. Land filling and land forming. Deep well injection. **Laboratory Sessions/ Experimental learning:** Landfill in a Bottle **Applications:** Students will understand how household/college waste breaks down in a landfill, recognize the impact of waste on the environment **Video link / Additional online information:** https://nptel.ac.in/courses/120/108/120108005/		
Module-4	**RBT Levels: L1, L2, L3**	**8 Hours**
MATERIAL RECOVERY: Mechanical size alteration. Electromagnetic separation. Drying and dewatering. Other material recovery systems. Recovery of biological conversion products. Recovery of thermal conversion products. **ENERGY RECOVERY**: Energy recovery systems and efficiency factors. Determination of output and efficiency. Details of energy recovery systems. Combustion incineration and heat recovery. Gasification and pyrolysis. Refuse derived fuels (RDF). **Laboratory Sessions/ Experimental learning:** Safe combustion reaction **Applications:** Students learn about chemistry, chemical reactions & energy by studying combustion reactions **Video link / Additional online information:** http://cpheeo.gov.in/upload/uploadfiles/files/chap15(1).pdf		
Module-5	**RBT Levels: L1, L2, L3**	**8 Hours**
HAZARDOUS WASTES: Classification. Origin and reduction at source. Collection and handling. Management issues and planning methods. Environmental Acts. **CASE STUDIES:** Major industries and management methods used in typical industries – Coal fired power stations, textile industry, oil refinery, distillery, sugar industry, radioactive and e-waste generation units. **Laboratory Sessions/ Experimental learning:** Minimizing the hazardous waste in the laboratories **Applications:** Students can understand the chemical management to minimize the generation of hazardous waste that might adversely affect the environment **Video link / Additional online information:** https://nptel.ac.in/courses/105/106/105106056/		

Scheme of Evaluation:		
Details		Marks
Average of three Internal Assessment (IA) Tests of 30 Marks each i.e., ∑ (Marks Obtained in each test)/3	CIE (50)	30
Quizzes - 2Nos.		2X2=4
Activities/ Experimentations related to course (1 in each module)		5X2=10
Mini Projects/ Case studies - 3Nos.		3X2=6
Semester End Examination	SEE (50)	50
	Total	100

Course Outcomes:	
CO1	Explain the physical and chemical characteristics of solid waste and Interpret the various techniques involved in reduction of solid waste.
CO2	Explain the various handling, storage, processing, collection, transfer & transport techniques involved in solid waste management
CO3	Explain the various handling and processing techniques involved in solid waste management.
CO4	Demonstrate the different techniques involved in material and energy recovery from solid waste
CO5	Explain various techniques to handle hazardous waste and outline the case study on solid waste management with respect to various chemical industries.

Text Books:	
1	George Tchobanoglous et al., Integrated Solid Waste Management,2ndedn, McGraw Hill & Co, 1993.
2	Dutta et al. Industrial Solid Waste Management and Land Filling Practice, Narosa Publishing House, 1999
Reference Books:	
1	Sastry C.A. et al, Waste Treatment Plants, Narosa Publishing House, 1995.
2	Lagrega, Hazardous Waste Management, McGraw Hill, 1994
3	Lagrega, Hazardous Waste Management, McGraw Hill, 1994

4	Web Link and Video Lectures: https://nptel.ac.in/courses/120108005/ https://nptel.ac.in/courses/105/103/105103205/ https://nptel.ac.in/courses/105/106/105106056/ https://nptel.ac.in/courses/105/105/105105160/

CO-PO MAPPING												
CO/PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	1	--	--	--	--	--	--	--	--	--	2	--
CO2	2	--	--	--	--	3	3	2	--	--	2	--
CO3	2	--	--	--	--	3	3	2	--	--	2	--
CO4	3	2	--	--	--	3	3	2	--	--	2	--
CO5	2	--	--	--	--	3	3	2	--	--	2	--

High-3, Medium-2, Low-1

Course Title	PROCESS CONTROL LAB	Semester	VII
Course Code	MVJ20CHL76	CIE	50
Total No. of Contact Hours	40 L: T: P:: 0: 10: 30	SEE	50
No. of Contact Hours/week	3	Total	100
Credits	2	Exam. Duration	3 Hours

Course objective is to:

- To verify experimentally the process control concepts studied in theory.
- To carry out experiment and make observations for various parameters.
- To study and use of various first order system, second order system and controllers.
- To evaluate the data and compare with reported literature.

Sl No	Experiment Name	RBT Level	Hours
1.	Determination of time constant of thermocouple	L1, L2, L3, L4	3
2.	Step response of a single tank system	L1, L2, L3, L4	3
3.	Step response of non-interacting Tanks	L1, L2, L3, L4	3
4.	Step Response of interacting tanks	L1, L2, L3, L4	3
5.	Transient behaviour of pressure vessel system	L1, L2, L3, L4	3
6.	Dynamics of a 2^{nd} order under damped process- U Tube Manometer	L1, L2, L3, L4	3
7.	Impulse Response of a single tank system	L1, L2, L3, L4	3
8.	Impulse Response of non-interacting Tanks	L1, L2, L3, L4	3
9.	Impulse Response of Interacting Tanks	L1, L2, L3, L4	3
10.	Level/Flow/Pressure/pH/Temperature control – P controller	L1, L2, L3, L4	3
11.	Level/Flow/Pressure/pH/Temperature control – PI controller	L1, L2, L3, L4	3
12.	Level/Flow/Pressure/pH/Temperature control – PD controller	L1, L2, L3, L4	3
13.	Level/Flow/Pressure/pH/Temperature control – PID controller	L1, L2, L3, L4	3
14.	Determination of valve characteristics	L1, L2, L3, L4	3

15	Characteristics of flapper nozzle system	L1, L2, L3, L4	3

Course outcomes:

CO1	Explain properties of particulate solids, handling and mixing of solid particles.
CO2	Analyse principles and different types of size reduction equipment's like crushers, grinders etc.
CO3	Evaluate the effectiveness of screening, filtration, sedimentation, of solids etc.
CO4	Evaluate energy requirements in solids handling, agitation and mixing, solid conveying and storage.
CO5	Conduct experiments on some of the basic unit operations such as separation size reduction.

Scheme of Evaluation		
Details		**Marks**
Regular Lab Work	CIE (50)	**20**
Record Writing		**5**
Lab Test (minimum 2 tests shall be conducted for 15 marks and average of two will be taken)		**15**
Viva		**10**
Write up	SEE (50)	**10**
Conduction		**20**
Analysis of results		**10**
Viva		**10**
Total		**100**

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	0	0	0	0	0	0	0	0	0
CO2	2	2	2	2	0	0	0	0	0	0	0	0
CO3	2	2	2	2	0	0	0	0	0	0	0	0
CO4	2	2	2	0	0	0	0	0	0	0	0	0
CO5	2	2	2	2	0	0	0	0	0	0	0	0

High-3, Medium-2, Low-1

Course Title	CHEMICAL PROCESS SIMULATION LAB	Semester	VII
Course Code	MVJ20CHL77	CIE	50
Total No. of Contact Hours	20	SEE	50
No. of Contact Hours/week	3 L:T:P::0:10:10	Total	100
Credits	2	Exam. Duration	3 Hours

Course objective is to:

Students will learn to use commercial process simulator for solving chemical process in chemical engineering operations.

The following experiments are to be carried out; the data are to be analysed based on the theoretical aspects and recorded with comments.

Sl No	Experiment Name	RBT Level	Hours
1.	Introduction to suggested software available (flow sheeting)	L1, L2, L3, L4	3
2.	2. Simulation of Shell and Tube Heat Exchanger	L1, L2, L3, L4	3
3.	3. Simulation of Centrifugal Pump/Compressor	L1, L2, L3, L4	3
4.	4. Simulation of Flash drum/Separator	L1, L2, L3, L4	3
5.	5. Simulation of single stream gas heater/cooler	L1, L2, L3, L4	3
6.	6. Simulation of CSTR for liquid phase reaction	L1, L2, L3, L4	3
7.	7. Simulation of Distillation Column	L1, L2, L3, L4	3
8.	8. Mixing of ideal liquid streams	L1, L2, L3, L4	3
9.	9. Generation of VLE data of binary component system	L1, L2, L3, L4	3
10.	10. Determination of equilibrium conversion of reversible reactions	L1, L2, L3, L4	3
11.	11. Material balance on reactor based on yield/conversion data	L1, L2, L3, L4	3
12.	12. Process simulation study involving mixing, reactor, distillation, heat exchanger for any of the following: a) Ethylene Glycol from Ethylene oxide b) Atmospheric distillation of crude oil c) Propylene Glycol from Propylene oxide	L1, L2, L3, L4	3

	d) Aromatic stripper with recycle stream (Benzene, Toluene, Xylene) e) Styrene from Ethyl Benzene		

Note:

- Minimum of 10 experiments are to be conducted and all 10 experiments are to included for practical examination.

Course outcomes:

CO1	Distinguish simulation from design of equipment.
CO2	Explain simulation of unit operations used in various chemical engineering operations.
CO3	Use simulation tools to verify and analyze chemical processes, and to determine optimal solutions.
CO4	Understand the application of simulation and data processing in chemical engineering
CO5	Understand process simulation study of industrially important chemical processes

Scheme of Evaluation:

Details		**Marks**
Daily Evaluation	**CIE (50)**	**30**
Internal Assessment		**10**
Project Based Experiment		**10**
Semester End Examination	**SEE (50)**	**50**
	Total	**100**

CO-PO Mapping												
CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	--	3	--	--	--	--	--	--	--
CO2	3	3	3	--	3	--	--	--	--	--	--	1
CO3	3	3	3	--	3	--	--	--	--	--	--	2
CO4	3	3	3	--	3	--	--	--	--	--	--	2
CO5	3	3	3	--	3	--	--	--	--	--	--	2

High-3, Medium-2, Low-1

Course Title	PROJECT PHASE – I	Semester	VII
Course Code	MVJ20CHP78	CIE	50
Total No. of Contact Hours	60 L : T : P :: 0 : 0 : 60	SEE	50
No. of Contact Hours/week	4	Total	100
Credits	2	Exam. Duration	3 Hours

Course Objective:

- To support independent learning.
- To develop interactive, communication, organization, time management, and presentation skills.
- To impart flexibility and adaptability.
- To inspire independent and team working.
- To expand intellectual capacity, credibility, judgment, intuition.
- To adhere to punctuality, setting and meeting deadlines.
- To instill responsibilities to oneself and others.
- To train students to present the topic of project work in a seminar without any fear, face audience confidently, enhance communication skill, involve in group discussion to present and exchange ideas.

Project Work Phase - I: Each student of the project batch shall involve in carrying out the project work jointly in constant consultation with internal guide, co-guide, and external guide and prepare the project report as per the norms avoiding plagiarism.

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

CO1	Describe the project and be able to defend it. Develop critical thinking and problem solving skills.
CO2	Learn to use modern tools and techniques. Communicate effectively and to present ideas clearly and coherently both in written and oral forms.
CO3	Develop skills to work in a team to achieve common goal. Develop skills of project management and finance.
CO4	Develop skills of self-learning, evaluate their learning and take appropriate actions to improve it.
CO5	Prepare them for life-long learning to face the challenges and support the technological changes to meet the societal needs.

Scheme of Evaluation :

Internal Marks: The Internal marks (50 marks) evaluation shall be based on Phase wise completion of the project work, Project report, Presentation and Demonstration of the actual/model/prototype of the project.

Semester End Examination: SEE marks for the project (50 marks) shall be based on Project report, Presentation and Demonstration of the actual/model/prototype of the project, as per the norms by the examiners appointed

CO-PO Mapping

CO/PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2	2	3	3	2	1	1	2	1	1	2
CO2	2	2	2	3	3	2	1	1	2	1	2	2
CO3	2	2	2	3	3	2	1	1	2	1	2	2
CO4	2	2	2	3	3	2	1	1	2	1	2	2
CO5	2	2	2	3	3	2	1	1	2	1	2	2

High-3, Medium-2, Low-1