Semester IV

Vertical – 1
Major

Detail Syllabus

Semester IV

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2074111	Chemical Engineering Thermodynamics-II	2	-	1	2	-	1	3

		Theory					Term Work (TW)	Oral and Pract	Total
		Internal Assessment Test (IAT)			End Sem Exam Marks	End Sem Exam Duration (Hrs)			
		IAT-I	IAT-II	Total (IAT-I + IAT-II)					
2074111	Chemical Engineering Thermodynamics-II	20	20	40	60	2	25	--	125

Rationale:

Thermodynamics is a fundamental subject in Chemical Engineering and knowledge of thermodynamics is required in the study of various unit operations and unit processes. The course Chemical Engineering Thermodynamics-I covers the basics of thermodynamics. In Chemical Engineering Thermodynamics-II more emphasis is given to the study of the properties of solutions, phase equilibria, vapour-liquid equilibria and chemical reaction equilibria. The topics covered in this course will serve as a foundation for the students in the study of courses on Mass Transfer Operations and Chemical Reaction Engineering in the subsequent semesters.

Course Objectives:

1. To compute the thermodynamic properties of ideal and non-ideal solutions and mixtures.
2. To explain thermodynamic concepts such as activity, chemical potential and excess property for solutions
3. To perform calculations and analyze problems related to phase equilibria.
4. To predict and analyze vapour-liquid equilibrium data for various systems.
5. To perform calculations and analyze problems related to chemical reaction equilibria.
6. To outline various types of refrigeration cycles and predict their performance.

Course Outcomes:

On completion of the course the students will be able to:

1. Evaluate the thermodynamic properties of ideal and non-ideal solutions and mixtures.

2. Perform calculations related to solution thermodynamics.

3. Analyze and solve the problems of phase equilibria.

4. Analyze and solve the problems of vapour-liquid equilibria.

5. Analyze and solve the problems of chemical reaction equilibria.

6. Describe various types of refrigeration cycles and evaluate their performance.

Prerequisites:

1. Chemical Engineering Thermodynamics-I.
2. Applied Mathematics and Engineering Mathematics.
3. Applied Physics and Elective Physics.
4. Applied Chemistry and Elective Chemistry.

DETAILED SYLLABUS:

Sr. No.	Name of Module	Detailed Content	Hours	CO Mapping
0	Prerequisites	-	-	-
1	**Ideal and Non-Ideal Solutions**	1.1 Ideal solutions and mixtures 1.2 Non-idealities of solutions and mixtures 1.3 Partial molar properties 1.4 Chemical potential	**03**	**CO1**
2	**Properties of Solutions**	2.1 Activity and activity coefficients 2.2 Gibbs-Duhem equation 2.3 Property changes of mixing 2.4 Excess properties	**04**	**CO2**
3	**Phase Equilibria**	3.1 Concept of equilibrium between phases 3.2 Review of Raoult's law and Henry's law 3.3 Phase diagrams for binary solutions	**03**	**CO3**
4	**Vapour-Liquid Equilibria**	4.1 Vapour-liquid equilibria in ideal and non-ideal solutions 4.2 Estimation of activity coefficients using Margules equations, van Laar equation and Wilson equation 4.3 Introduction to UNIQUAC equation and UNIFAC method 4.4 Consistency tests for VLE data	**05**	**CO4**
5	**Chemical Reaction Equilibria**	5.1 Representation of reaction stoichiometry 5.2 Concept of reaction equilibrium in single and multiple reactions 5.3 Estimation of standard Gibbs free energy change and equilibrium constant of a reaction 5.4 Estimation of degree of conversion and composition of reactor effluents for single and multiple reactions 5.5 Degrees of freedom for single and multiple reactions	**07**	**CO5**
6	**Refrigeration**	6.1 Theory of Refrigeration 6.2 Vapour compression refrigeration system 6.3 Vapour absorption refrigeration system 6.4 Estimation of COP, refrigerant flow rate and power consumption	**04**	**CO6**

Text Books:

1. J.M. Smith, H.C. Van Ness, M.M. Abbot, M.T. Swihart, Introduction to Chemical Engineering Thermodynamics, 8th Edition, McGraw-Hill Education, 2017.

2. K.V. Narayanan, A Textbook of Chemical Engineering Thermodynamics, 2nd Edition, Prentice Hall of India Pvt. Ltd., 2013.

3. Y.V.C. Rao, Chemical Engineering Thermodynamics, Universities Press, 1997.

References:

1. M.J. Moran, H.N. Shapiro, D.D. Boettner, M.B. Bailey, Fundamentals of Engineering Thermodynamics, 9th Edition, Wiley, 2018.

2. Gopinath Halder, Introduction to Chemical Engineering Thermodynamics, 2nd Edition, Prentice Hall of India Pvt. Ltd., 2014.

3. S. Sandler, Chemical, Biochemical and Engineering Thermodynamics, 5th Edition, John Wiley and Sons, 2017.

4. J. Richard Elliot and Carl T. Lira, Introductory Chemical Engineering Thermodynamics, 2nd Edition, Prentice Hall, 2012.

Online References:

Sr. No.	Website Name
1.	https://archive.nptel.ac.in/courses/103/101/103101004/

Term Work:

1. Batch-wise tutorials are to be conducted. The number of students per batch should be as per University pattern for practicals.
2. The tutorial questions should consist of numerical problems and mathematical derivations based on all the six modules of the syllabus covered in the theory lectures.
3. Each student must submit a minimum of ten tutorials as term work.

The distribution of Term Work marks will be as follows:-

1.	Attendance (Theory Lectures and Tutorials)	05 Marks
2.	Class Tutorials (minimum ten) on entire syllabus	20 Marks

Assessment:

Internal Assessment Test (IAT) for 20 marks:

- IA will consist of Two Compulsory Internal Assessment Tests. Approximately 40% to 50% of syllabus content must be covered in First IA Test and remaining 40% to 50% of syllabus content must be covered in Second IA Test.

End Semester Theory Examination:

- **Question paper format**
  - Question Paper will comprise of a total of **six questions each carrying 15 marks. Q.1** will be **compulsory** and should **cover maximum contents of the syllabus.**
  - **Remaining questions** will be **mixed in nature** (part (a) and part (b) of each question must be from different modules. For example, if Q.2 has part (a) from Module 3 then part (b) must be from any other Module randomly selected from all the modules.
  - A total of **four questions** need to be answered.

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Prac.	Tut.	Theory	Prac.	Tut.	Total
2074112	Solid Fluid Mechanical Operations	3	-	-	3	-	-	3

		Theory					Term Work (TW)	Oral and Pract	Total
		Internal Assessment Test (IAT)			End Sem Exam Marks	End Sem Exam Duration (Hrs)			
		IAT-I	IAT-II	Total (IAT-I + IAT-II)					
2074112	Solid Fluid Mechanical Operations	20	20	40	60	2	-	--	100

Rationale:
A "solid-fluid mechanical operation" refers to a set of industrial operations that involve the handling and processing of solid particles, either in the presence or absence of a fluid, utilizing mechanical methods like size reduction, separation, mixing, and conveying, often used in chemical engineering and related fields to evaluate particle size, composition, and flow characteristics within a system; essentially, it's the science and technology of working with powders and granular materials, including their interactions with fluids. Solid-fluid operations are widely used in industries like pharmaceuticals, mining, food processing, chemical manufacturing, and waste management. Common solid fluid mechanical operations are size reduction, size separation, mixing, fluidization, filtration, flotation etc.

Course Objectives:

1. Familiarize particle size distribution
2. Learn size reduction principles
3. Understand solid fluid mixing
4. Understand fluidization and filtration
5. To have knowledge of solid fluid separation
6. Understand storage and handling of solids

Course Outcomes:

1. Apply the concept of particle size distribution and identify the equipment

2. Explain size reduction principles
3. Explain solid fluid mixing
4. Compute the fluidization and filtration parameters
5. Design solid fluid separation equipment
6. Discuss the techniques for storage and handling of solids

Prerequisite:

1. Fluid flow operations
2. Engineering mechanics
3. Introduction to Chemical Engineering
4. Differential equations

DETAILED SYLLABUS:

Sr. No.	Name of Module	Detailed Content	Hours	CO Mapping
1	**Particle size**	Particle size measurement and distribution using sieve analysis. Capacity and effectiveness of screen. (Numericals) Screening equipment – Vibrating screen, Grizzlies and Trommels.	05	1
2	**Size Reduction**	Size reduction of solids. Mechanism of size reduction and method of operation. Energy requirement for size reduction and crushing laws. (Numericals) Size reduction equipment – Jaw crusher, Hammer mill, Ball mill and Roll crusher. (Numericals)	07	2
3	**Mixing**	Solid mixing – Introduction to solid mixing, degree of mixing and rate of mixing. (Numericals) Mixing equipment for cohesive solids: Muller mixer and kneaders. Mixers for free flowing solids: Ribbon blender and internal screw mixer.	05	3
4	**Fluidization and Filtration**	Flow of a single fluid through a packed bed, Ergun's equation. Fluidization: conditions for fluidization. Minimum fluidization velocity. Types of fluidization. Applications of fluidization. Filtration: Mechanism of filtration. Types of filtration: constant rate and constant pressure filtration. Filter aids, washing of filter cake, flow of filtrate through the cloth and cake combined. (Numericals) Filters: Rotary drum vacuum filter, plate and frame filter press.	10	4
5	**Solid fluid separation**	Sedimentation: Batch sedimentation. Kynch theory of sedimentation. Derivation of area and depth of thickener. (Numericals) Particle separation by flotation and elutriation.	08	5

		Gas solid separation equipment: Cyclone separator, fabric filter and electrostatic precipitator.		
6	**Storage and handling of solids**	Storage of solids: Properties of particulate masses. Pressure in bins and silos, Jansen's equation. Conveying, of solids: Belt conveyer, bucket conveyer, screw conveyer and pneumatic conveyer.	05	6

Text Books

1. W. McCabe, J.C. Smith and P. Harriot, Unit operations of chemical engineering, 7th edition, McGraw Hill, 2004.
2. J .M Coulson and J. F Richardson, Chemical Engineering, vol 2, Pergamon Press, 1974.
3. A.S. Foust and L.A. Wenzel, Principles of unit operation, 2nd edition, Wiley, 1980.

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Reference

1. Perry's Chemical Engineers' Handbook , Robert H. Perry & Don W. Green, 8th edition, McGraw Hill

Online References:

Sr. No.	Website Name
2.	https://onlinecourses.nptel.ac.in/noc23_ch47/preview#
3.	https://archive.nptel.ac.in/courses/103/103/103103155/
3.	https://www.scribd.com/document/386040724/103107090-pdf

Assessment:

Internal Assessment (IA) for 20 marks:

- IA will consist of Two Compulsory Internal Assessment Tests. Approximately 40% to 50% of syllabus content must be covered in First IA Test and remaining 40% to 50% of syllabus content must be covered in Second IA Test

- **Question paper format**
- Question Paper will comprise of a total of **six questions each carrying 15 marksQ.1** will be **compulsory** and should **cover maximum contents of the syllabus**
- **Remaining questions** will be **mixed in nature** (part (a) and part (b) of each question must be from different modules. For example, if Q.2 has part (a) from Module 3 then part (b) must be from any other Module randomly selected from all the modules)
- A total of **four questions** need to be answered

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2074113	Heat Transfer Operations	3	-	-	3	-	-	3

		Theory					Term work	Pract / Oral	Total
		Internal Assessment (IAT)			End Sem Exam	Exam Duration (in Hrs)			
		IAT-I	IAT-II	Total (IAT-I + IAT-II)					
2074113	Heat Transfer Operations	20	20	40	60	2	--	--	100

Rationale:
A basic course that deals with heat transfer, heat exchangers and their design is typically called "Heat Transfer Fundamentals" within a Chemical Engineering curriculum, which are crucial for understanding and designing various chemical processes and equipment, making it a vital component of chemical engineering education.

Course Objectives:

1. To learn basic concepts of heat transfer and study steady and unsteady heat conduction.
2. To study Natural and Forced convection with its empirical correlations.
3. To develop heat transfer system with phase change i.e. condensation & boiling.
4. To understand various laws and rate of heat transfer by radiation.
5. To study preliminary design, construction, working of heat exchangers.
6. To understand construction and working of evaporators.

Course Outcomes:

1. Understand conductive heat transfer and calculate temperature profiles at steady state.
2. Comprehend natural and forced convection and calculate the heat transfer coefficients.
3. Interpret condensation and boiling phenomena and calculate heat duty in both the processes.
4. Acknowledge the radiative heat transfer.
5. Recognize the rate performance using NTU method and calculate heat duty /outlet/Temperatures / pressure drops / area required for various heat exchangers.
6. Know the process design aspects of evaporators.

Prerequisite: Applied mathematics-I & II, Material and Energy balance Calculations, Units and Dimensions, Laws of Thermodynamics

DETAILED SYLLABUS:

Sr. No.	Name of Module	Detailed Content	Hours	CO Mapping
1	**Conduction**	Basic Fundamentals and Modes of Heat Transfer with its rate expressions. Concept of Thermal Resistance and Heat Transfer Coefficient **Steady State Conduction:** Fourier's Law, thermal conductivity, conduction through a flat slab, composite slab, conduction through a cylinder wall, composite cylinder, Conduction through hollow sphere, composite sphere. Critical radius of insulation. **Unsteady state conduction:-**Lumped Parameter Analysis – systems with negligible internal resistance. Biot number. Fourier number, Numericals.	**8**	**CO1**
2	**Convection: Heat Transfer without Phase Change:**	**Natural Convection:** Introduction, Natural convection currents. Heat transfer correlations. Numericals. **Forced Convection:** Introduction, thermal and hydrodynamic boundary layer, Heat transfer in laminar and turbulent boundary layers. Significance of various dimensionless numbers. Empirical correlations. Various analogies. Numericals.	**7**	**CO2**
3	**Condensation & Boiling: Heat Transfer with Phase Change**	**Condensation:** Introduction, types of condensation, Nusselt's theory of condensation, correlations for vertical and horizontal tube, plate. Numericals. **Boiling:** Heat transfer to boiling liquids, Pool Boiling Curve, Correlations for estimating the boiling heat transfer coefficients.	**3**	**CO3**
4	**Radiation**	Introduction, Radiation Fundamentals, Laws of radiations. Radiative heat exchange between surfaces, Multiple reflection method, Radiation shield. Heat Transfer in Furnaces. Numericals.	**4**	**CO4**
5	**Heat Exchangers**	Introduction, Types of flow, energy balance, rate of heat transfer, individual and Overall Heat Transfer Coefficients, LMTD, Wilson plot and fouling factors. Classification of Heat Exchangers. Preliminary process design of Double pipe heat exchangers. TEMA exchanger types, their nomenclature, choice of exchanger type, Design of Shell & tube heat exchangers: by Kerns method. Bell Delaware method.	**14**	**CO5**

		Effectiveness-NTU method. Heat transfer in agitated vessels and correlations, Extended surface heat exchangers, Fin efficiency and fin effectiveness, calculation of rate of heat transfer. Plate Heat Exchanger, Spiral Heat Exchanger. Numericals.		
6	**Evaporators**	Types of Evaporators, Performance, Capacity and Economy, Boiling Point Elevation, Methods of Feeding for MEE. Process design aspects of evaporators.	**3**	**CO6**

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Text Books:

1. MaCabe W. L., Smith J. C., Harriot P., Unit Operations of Chemical Engineering, 5th edition, McGraw Hill,1993.
2. Cengel, Y. A. (2006). Fluid mechanics: fundamentals and applications. New Delhi, India: Tata McGraw-Hill Publishing.
3. D. Q. Kern, Process Heat Transfer, McGraw hill, 1997.
4. R. K. Sinnot, Coulson & Richardsons Chemical Engineering Design, Vol 1 & 6, Elsevier Science & Technology Books.

References:

1. Holman J. P., Heat Transfer, 9th Edition, McGraw Hill, 2008.
2. B. K. Datta, Heat Transfer: Principles and applications, PHI learning

Online References:

Sr. No.	Website Name
4.	NPTEL
5.	SWAYAM
3.	Udemy

Assessment:

Internal Assessment (IA) for 20 marks:

- IA will consist of Two Compulsory Internal Assessment Tests. Approximately 40% to 50% of syllabus content must be covered in First IA Test and remaining 40% to 50% of syllabus content must be covered in Second IA Test

Question paper format

- Question Paper will comprise of a total of **six questions each carrying 15 marks Q.1** will be **compulsory** and should **cover maximum contents of the syllabus**
- **Remaining questions** will be **mixed in nature** (part (a) and part (b) of each question must be from different modules. For example, if Q.2 has part (a) from Module 3 then part (b) must be from any other Module randomly selected from all the modules)
- A total of **four questions** need to be answered

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract	Tut.	Theory	Pract	Tut.	Total
2074114	Solid Fluid Mechanical Operation Lab	–	2	–	–	1	–	1

Course Code	Course Name	Examination Scheme						
		Theory Marks				Term Work	Practical/ Oral	Total
		Internal assessment			End Sem. Exam			
		IAT-I	IAT-II	Total (IAT-I + IAT-II)				
2074114	Solid Fluid Mechanical Operation Lab	--	--	--	--	25	25	50

Lab Objectives:

1. Understand the importance of various mechanical operations used in process industry
2. Apply principles of basic sciences and chemical engineering for designing various size reduction and separation equipment.
3. Understand particulate solid characterization.
4. Familiarize primary and secondary crushers.
5. Acquire knowledge of mixing operation.
6. Understand filtration and sedimentation operation.

Lab Outcomes:

1. Acquire analytical skills for determination of particle size of solid mixture and determining the effectiveness of screen
2. Understand the operation of various equipment and applying laws of crushing
3. Understand the operation of mixing and evaluating the mixing index

4. Understand the operation of fluidization and filtration parameters
5. Understanding the sedimentation process and design of thickener
6. Understanding the concept of gas solid separation.

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Prerequisite:

1. Fluid Flow Operations
2. Basic knowledge on mechanical operations
3. Introduction to Chemical Engineering
4. Differential Equations

List of Experiments

Sr No	List of Experiments	Hrs
01	Sieve Analysis	2
02	Effectiveness of screen	2
03	Size reduction by jaw crusher	2
04	Size reduction by hammer mill	2
05	Size reduction by ball mill	2
06	Size reduction by Roll crusher	2
07	Batch sedimentation	2
08	Flow through fluidized bed	2
09	Filtration	2
10	Mixing	2
11	Cyclone separator	2
12	Elutriation	2
13	Froth floatation	2
14	Experiments using virtual labs	2

Assessment:
Term Work: Term Work shall consist of at least 10 to 12 practical's based on the above list. Also, Term work Journal must include at least 2 assignments.
Term Work Marks: 25 Marks (Total marks) = 15 Marks (Experiment) + 5 Marks (Assignments) + 5 Marks (Attendance)
Practical& Oral Exam: An Oral & Practical exam will be held based on the above syllabus.
Text Books

1. W. McCabe, J.C. Smith and P. Harriot, Unit operations of chemical engineering, 7th edition, McGraw Hill, 2004.
2. J .M Coulson and J. F Richardson, Chemical Engineering, vol 2, Pergamon Press, 1974.

Online References:

Sr. No.	Website Name
6.	https://onlinecourses.nptel.ac.in/noc23_ch47/preview#
7.	https://archive.nptel.ac.in/courses/103/103/103103155/
3.	https://www.scribd.com/document/386040724/103107090-pdf

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Reference

1. Perry's Chemical Engineers' Handbook , Robert H. Perry & Don W. Green, 8th edition, McGraw Hill
2. A.S. Foust and L.A. Wenzel, Principles of unit operation, 2nd edition, Wiley, 1980.

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2074115	Heat Transfer Operations Lab	–	2	–	–	1	–	1

Course Code	Course Name	Examination Scheme						
		Theory Marks				Term Work	Practical / Oral	Total
		Internal assessment (IAT)			End Sem. Exam			
		IAT-I	IAT -II	Total (IAT-I + IAT-II)				
2074115	Heat Transfer Operations Lab	--	--	--	--	25	25	50

Prerequisites:

1. Knowledge of fluid, flow pattern and properties of fluids.
2. Knowledge of flow measurement and temperature measurement devices.
3. Knowledge of basic process calculations and process safety.

Lab Objectives: (Students should be able……)

1. To gain hands-on experience of lab-scale experiments on conductive heat transfer systems.
2. To define the fundamental concepts to students in the area of convective heat transfer systems.
3. To determine the heat transfer rate and heat transfer coefficient in phase change systems such as condensation and boiling.
4. To apply the knowledge of radiative heat transfer in an effective manner for different applications.
5. To observe and record the steady state temperatures and evaluate the heat transfer coefficient, effectiveness of heat exchangers, agitated vessel and evaporators in chemical industries.
6. To familiar themselves with software's like Excel, HTRI, ANSI etc. for design of heat transfer equipment's.

Lab Outcomes: (On completion of the course the students will be able to……)

1. Determine the thermal conductivity and heat transfer rate by using Fourier's law.
2. Evaluate the heat transfer coefficient for natural and force convection.
3. Estimate the heat transfer coefficient in drop wise and film wise condensation.
4. Determine the rate of heat transfer in radiation.

5. Analyze heat exchanger performance by using the method of log mean temperature difference and Measure the heat transfer coefficient in agitated vessel and efficiency in evaporator.
6. Design and calculate the performance of heat Exchangers by using Excel, HTRI, ANSI software's.

List of Experiment

Experiment No.	Name of Experiment	Lab Hours
1	Heat Transfer by Conduction (Insulating Materials / Composite Wall)	2
2	Thermal Conductivity of Fluid	2
3	Unsteady State Conduction	2
4	Natural Convection	2
5	Forced Convection	2
6	Film wise and Drop wise Condensation	2
7	Emissivity Measurement Apparatus	2
8	Double Pipe Heat Exchanger	2
9	Shell and Tube Heat Exchanger	2
10	Plate Heat Exchanger	2
11	Finned tube heat exchanger	2
12	Agitated vessel	2
13	Spiral Heat Exchanger	2
14	Evaporator	2
15	Design of Shell and Tube Heat Exchanger by Kerns method (Virtual Lab / software)	2
16	Design of Shell and Tube Heat Exchanger by Bell Delaware method (Virtual Lab / software)	2

Assessment:

Term Work: Term Work shall consist of at least 10 practical's based on the above list. Also, Term work Journal must include at least 5 assignments.

Term Work (25 marks)

Distribution of marks will be as follows:

Laboratory work: 15 marks

Assignments: 05

Attendance: 05

End Semester Practical Examination/Orals (25 marks):

Practical Examination will be based on experiments performed in the laboratory.

Reference Books:

1. Holman J. P., Heat Transfer, 9th Edition, McGraw Hill, 2008.
2. B. K. Datta, Heat Transfer: Principles and applications, PHI learning.
3. R. K. Sinnot, Coulson & Richardsons Chemical Engineering Design, Vol 1 & 6, Elsevier Science & Technology Books
4. Software's like Excel, HTRI, ANSI etc.

Vertical – 4

VSC

Detailed syllabus

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2074411	Mini Project-II	–	2	–	–	1	–	1

Course Code	Course Name	Examination Scheme						
		Theory				Term Work	Pral/ Oral	Total
		Internal Assessment (IAT)			End Sem Exam			
		IAT-1	IAT-II	Total (IAT-I + IAT-II)				
2074411	Mini Project-II	–	–	–	–	25	25	50

Course Objectives :

1. To acquaint with the process of identifying the needs and converting it into the problem.
2. To provide knowledge of unit operation and unit process.
3. To familiarize the process of solving the problem in a group.
4. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems.
5. To inculcate the process of self-learning and research.
6. Design and development of Small project based on various process and software

Course Outcome: Learner will…

1. Identify problems based on societal /research needs.
2. Reproduce, improve and refine technical aspects for engineering projects.
3. Draw the proper inferences from available results through theoretical/ experimental / simulation
4. Identify, discuss and justify the technical aspects of the chosen project with a comprehensive and systematic approach.
5. Students will be able to practice acquired knowledge within the chosen area of technology for project development.
6. Work as an individual or in a team in development of technical projects, which leads to lifelong learning.

2. **Guidelines for Mini Project**

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problem statement for mini project in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students hall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty supervisor may give inputs to students during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert the best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.
- Mini Projects should focus on self-learning, innovation, solving societal problems, and developing entrepreneurial skills, and it is preferred that a single, meaningful project be continued over the semester for deeper learning and better outcomes.
- However, based on the individual students or group capability, with the mentor's recommendations, if the proposed Mini Project adhering to the qualitative aspects mentioned above gets completed in odd semester, then that group can be allowed to work on the extension of the Mini Project with suitable improvements/modifications or a completely new project idea in even semester. This policy can be adopted on case by case basis.

Guidelines for Assessment of Mini Project:

Term Work

- The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.
- Distribution of Term work marks for both semesters shall be as below;
  - Marks awarded by guide/supervisor based on log book: 20
  - Marks awarded by review committee: 20
  - Quality of Project report: 10

Assessment Criteria for Term Work (Internal Assessment):

Mini Project shall be assessed based on following criteria;

1. Quality of survey/ need identification
2. Clarity of Problem definition based on need.
3. Innovativeness in solutions
4. Feasibility of proposed problem solutions and selection of best solution
5. Cost effectiveness
6. Societal impact
7. Innovativeness
8. Cost effectiveness and Societal impact
9. Full functioning of working model as per stated requirements
10. Effective use of skill sets
11. Effective use of standard engineering norms
12. Contribution of an individual's as member or leader
13. Clarity in written and oral communication

Guidelines for Assessment of Mini Project Practical/Oral Examination:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners preferably from industry or research organisations having experience of more than five years approved by head of Institution.
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Vertical – 5

Detailed syllabus

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2994511	Business Model Development		2*+2	-	2*	2	-	2

Course Code	Course Name	Theory					Term work	Pract / Oral	Total
		Internal Assessment			End Sem Exam	Exam Duration (in Hrs)			
		IAT-I	IAT-II	IAT-I+IAT-II					
2994511	Business Model Development	--	--	--	--	--	50	--	50

Note: * Two hours of practical class to be conducted for full class as demo/discussion/theory.

Lab Objectives:

1. To introduce a learner to entrepreneurship and its role in economic development.
2. To familiarize a learner with the start-up ecosystem and government initiatives in India.
3. To explain the process of starting a business.
4. To familiarize a learner with the building blocks of a business.
5. To teach a learner to plan their own business with the help of Business Model Canvas.
6. To teach a learner to have financial plan for a business model.

Lab Outcomes:

The learner will be able to:

1. Discuss the role of entrepreneurship in the economic development of a nation and describe the process of starting a business.
2. Describe start-up ecosystems in Indian and global context.
3. Identify different types of business models.
4. Identify customer segments, channels and customer relationship components for a particular business.
5. Identify key activities, key partners and key resources for a particular business.
6. Develop a financial plan for a business with the help of cost structure and revenue model.

DETAILED SYLLABUS:

Sr. No.	Module	Detailed Content	Hours	LO Mapping
0	**Prerequisite**	Basic Design Thinking principles	**01**	**L2**
I	**Introduction to Entrepreneurship**	**Introduction to Entrepreneurship**: Definition, the role of entrepreneurship in the economic development, the entrepreneurial process, Women entrepreneurs, Corporate entrepreneurship, Entrepreneurial mindset **Self-learning Topics:** Case	**04**	**L2, L3**

		studies: Henry Ford https://www.thehenryford.org/docs/default-source/default-document-library/default-document-library/henryfordandinnovation.pdf?sfvrsn=0 The Tatas: How a Family Built a Business and a Nation by Girish Kuber, April 2019, Harper Business		
II	**Entrepreneurship Development**	**Entrepreneurship Development**: Types of business ownerships: Proprietorship, Public and Private Companies, Co-operative businesses, Micro, Small and Medium Enterprises (MSME): Definition and role of MSMEs in economic development	**05**	**L2, L3**
III	**Start-up financing**	**Start-up financing:** Cost and revenue models, Sources of start-up fundings: Angel investors, Venture capitalists, Crowd funding, Government schemes for start-up funding **Self-learning Topics:** Successful business pitching	**04**	**L2, L3**
IV	**Intellectual Property Rights (IPR)**	**Intellectual Property Rights (IPR):** Types of IPR: Patents, trademarks and copyrights, Patent search and analysis, Strategies for IPR protection, Ethics in technology and innovation	**04**	**L2,L3**
V	**Business Model Development**	**Business Model Development:** Types of business models, Value proposition, Customer segments, Customer relationships, Channels, Key partners, Key activities, Key resources, Prototyping and MVP **Self-learning Topics:** The Art of the Start 2.0: The Time-Tested, Battle-Hardened Guide for Anyone Starting Anything by Guy Kawasaki	**04**	**L5, L6**
VI	**Digital Business Management**	**Digital Business Management:** Digital Business models (Subscription, Freemium *etc*), Digital marketing: Search Engine Optimization (SEO), Search Engine Marketing	**04**	**L2, L3**

		(SEM), Social media and influencer marketing, Disruption and innovation in digital business **Self-learning Topics:** Case study: Airbnb https://www.prismetric.com/airbnb-business-m		

Textbooks:

1. Entrepreneurship: David A. Kirby, McGraw Hill, 2002
2. Harvard Business Review: Entrepreneurs Handbook, HBR Press, 2018
3. Business Model Generation; Alexander Ostlewalder and Yves Pigneur, Strategyzer, 2010
4. E- Business & E– Commerce Management: Strategy, Implementation, Practice – Dave Chaffey, Pearson Education

Reference books:

1. Entrepreneurship: New venture creation by David Holt, Prentice Hall of India Pvt. Ltd.
2. E- Business & E– Commerce Management: Strategy, Implementation, Practice – Dave Chaffey, Pearson Education

Online Resources:

Sr. No.	Website Name
6.	Entrepreneurship by Prof. C Bhaktavatsala Rao https://onlinecourses.nptel.ac.in/noc20_mg35/preview
7.	Innovation, Business Models and Entrepreneurship by Prof. Rajat Agrawal, Prof. Vinay Sharma https://onlinecourses.nptel.ac.in/noc21_mg63/preview
3.	Sarasvathy's principles for effectuation https://innovationenglish.sites.ku.dk/model/sarasvathy-effectuation/

List of Experiments.

The lab activities are to be conducted in a group. One group can be formed with 4-5 students. A group has to develop a Business Model Canvas and a digital prototype (Web App/ mobile app). Weekly activities are to be conducted as follows:

Sr No	Lab activities	Hrs
01	Problem identification (Pain points, Market survey)	2
02	Design a digital solution for the problem (Ideation techniques)	2
03	Preparing a business model canvas: Value proposition, Key partners, Key resources, Key activities	2
04	Preparing a business model canvas: Customer segment, Customer relationships and channels	2
05	Preparing a business model canvas: Cost and Revenue structure	2
06	Prototype development: Low fidelity	2
07	Prototype development: Customer feedback	2
08	Prototype development: High fidelity	2
09	Presentation of high-fidelity prototype	2

Sr No	List of Assignments / Tutorials	Hrs
01	Presentation on case study of a failed business model	2
02	Presentation on case study of a woman entrepreneur	2

Assessment:

Term Work: Term Work shall consist of 10 lab activities based on the above list. Also, Term work journal must include any 2 assignments from the above list.

Term Work Marks: 50 Marks (Total marks) = 25 Marks (Experiment) + 10 Marks (Assignments) + 5 Marks (Attendance)+10 Marks (Report).

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Pract.	Tut.	Theory	Pract.	Tut.	Total
2994512	Design Thinking		2*+2	-	2*	2	-	2

Course Code	Course Name	Theory					Term work		Total
		Internal Assessment			End Sem Exam	Exam Duration (in Hrs)			
		IAT-I	IAT-II	IAT-I+IAT-II					
2994512	Design Thinking	--	--	--	--	--	50		50

Note: * Two hours of practical class to be conducted for full class as demo/discussion/theory.

Lab Objectives:

1. To introduce a learner to the principles of Design Thinking.
2. To familiarize a learner with the process (stages) of Design Thinking.
3. To introduce various design thinking tools.
4. Study of the techniques for generation of solutions for a problem.
5. To expose a learner to various case studies of Design Thinking.
6. Create and test a prototype.

Lab Outcomes:

Students will be able to …

1. Compare traditional approach to problem solving with the Design Thinking approach and discuss the principles of Design Thinking
2. Define a user persona using empathy techniques
3. Frame a problem statement using various Design Thinking tools
4. Use ideation techniques to generate a pool of solutions for a problem
5. Create prototypes using different techniques
6. Test the prototypes and gather feedback for refining the prototype

DETAILED SYLLABUS:

Sr. No.	Module	Detailed Content	Hours	LO Mapping
0	Prerequisite	No perquisites	-	-
I	**Introduction to Design Thinking**	**Introduction to Design Thinking:** Definition, Comparison of Design Thinking and traditional problem-solving approach, Need for Design Thinking approach, Key tenets of Design Thinking, 5 stages of Design Thinking (Empathize, Define, Ideate, Prototype, Test) **Self-learning Topics:** Design thinking case studies from various domains https://www.design-thinking-association.org/explore-design-thinking-	**05**	**L1, L2**

		topics/external-links/design-thinking-case-study-index		
II	**Empathy**	**Empathy:** Foundation of empathy, Purpose of empathy, Observation for empathy, User observation technique, Creation of empathy map **Self-learning Topics:** Creation of empathy maps https://www.interaction-design.org/literature/topics/empathy-mapping	**05**	**L2, L3**
III	**Define**	**Define:** Significance of defining a problem, Rules of prioritizing problem solving, Conditions for robust problem framing, Problem statement and POV **Self-learning Topics:** Creating a Persona – A step-by-step guide with tips and examples https://uxpressia.com/blog/how-to-create-persona-guide-examples	**05**	**L2, L3**
IV	**Ideate**	**Ideate:** What is ideation? Need for ideation, Ideation techniques, Guidelines for ideation: Multi-disciplinary approach, Imitating with grace, Breaking patterns, Challenging assumptions, Looking across value chain, Looking beyond recommendation, Techniques for ideation: Brainstorming, Mind mapping **Self-learning Topics:** How To Run an Effective Ideation Workshop: A Step-By-Step Guide https://uxplanet.org/how-to-run-an-effective-ideation-workshop-a-step-by-step-guide-d520e41b1b96	**05**	**L3, L7**
V	**Prototype**	**Prototype:** Low and high-fidelity prototypes, Paper prototype, Story board prototype, Scenario prototype	**03**	**L6**
VI	**Test**	**Test:** 5 guidelines of conducting test, The end goals of test: Desirability, Feasibility and Viability, Usability testing	**03**	**L4, L5**

Textbooks:

1. Design Your Thinking: The Mindsets, Toolsets, and Skill Sets for Creative Problem-solving, Pavan Soni, Penguin Random House India Private Limited
2. Design Thinking: Methodology Book, Emrah Yayichi, 2016
3. Handbook of Design Thinking: Christian Mueller-Roterberg, 2018

Reference books:

1. Design Thinking for Strategic Innovation: What They Can't Teach You at Business or Design School, Idris Mootee, Wiley, 2013
2. Change by Design, Tim Brown, Harper Business, 2009

Online Resources:

Sr. No.	Website Name
8.	Design Thinking and Innovation by Ravi Poovaiah https://onlinecourses.swayam2.ac.in/aic23_ge17/preview
9.	Introduction to Design Thinking by Dr. Rajeshwari Patil, Dr. Manisha Shukla, Dr. Deepali Raheja, Dr. Mansi Kapoor https://onlinecourses.swayam2.ac.in/imb24_mg37/preview
3.	Usability Testing https://www.interaction-design.org/literature/topics/usability-testing

List of Experiments.

The experiments are to be performed in groups. A practical batch may be divided into groups of 4-5 students.

Sr No	List of Experiments	Hrs
01	Customer Journey Mapping: Visualize the steps users take to interact with a product or service. Map out the customer journey from discovering a product to making a purchase and using the product. Identify pain points and opportunities for improvement.	2
02	Stakeholder mapping: Identify all relevant stakeholders in a project. Create a stakeholder map, categorizing stakeholders based on their influence and interest. Include management of relationships with key stakeholders.	2
03		
04	Brainstorming Session: Generate a pool of ideas in a creative, non-judgmental environment. Using ideation techniques like mind mapping and brainwriting, students brainstorm as many solutions as possible to their "How Might We" problem statements.	2
05	Affinity Diagramming: Organize group ideas to find patterns and insights. After brainstorming, students will categorize their ideas into themes by placing sticky notes on a wall and moving them into groups based on similarities.	2
06	Rapid Prototyping: Create quick, low-fidelity versions of solutions. Use materials like paper, cardboard, and markers to build a prototype of their solution within 30 minutes. The focus is on speed and functionality, not aesthetics.	2
07	Wireframing: Create a visual guide for digital interfaces for mobile app / web app for the problems identified in earlier lab sessions. Students will sketch wireframes of the user interface for their product or service. Use tools like Balsamiq or paper and pen for low-fidelity wireframes.	2
08	Role-Playing: Walk through a prototype from the user's perspective. Students act as both users and designers, role-playing scenarios where they interact with their prototype (Developed in earlier lab sessions). Gather feedback from participants on how to improve the experience.	2
09	Usability Testing: Evaluation of the effectiveness and user-friendliness of a prototype (developed in earlier lab sessions). Students will have peers or target users test their prototypes, observe how they interact with it, and collect feedback on any issues or improvements needed.	2
10	Feedback Loop and Iteration: Refine solutions based on user feedback. After usability testing, students will refine their prototypes. Document changes made based on feedback and discuss how continuous iteration improves the design.	2

Sr No	List of Assignments (Any two)	Hrs
01	Create an empathy map for a target user group. Break them into four sections: *Says, Thinks, Feels, and Does*. Interview users or research their experiences to fill in the map.	3
02	Based on research, students will create user personas including demographic details, motivations, pain points, and goals. Each group will present their persona to the class.	3
03	Consider 3 examples of real-life products which have good design and bad design. Write down reasons why do you think they are good or bad designs. May take user survey to support your work.	3
04	Study any open-source design thinking tool and write a brief report about it.	3

Assessment:

Term Work: Term Work shall consist of 10 to 12 lab activities based on the above list. Also, Term work journal must include any 2 to 4 assignments from the above list.

Term Work Marks: 50 Marks (Total marks) = 25 Marks (Experiment) + 10 Marks (Assignments) + 5 Marks (Attendance)+ 10 Marks (Report).

Letter Grades and Grade Points:

Semester GPA/ Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign/ Letter Grade Result	Grading Point
9.00 - 10.00	90.0 – 100	O (Outstanding)	10
8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)	9
7.00 - < 8.00	70.0 - < 80.0	A (Very Good)	8
6.00 - < 7.00	60.0 - < 70.0	B+ (Good)	7
5.50 - < 6.00	55.0 - < 60.0	B (Above Average)	6
5.00 - < 5.50	50.0 - < 55.0	C (Average)	5
4.00 - < 5.00	40.0 - < 50.0	P (Pass)	4
Below 4.00	Below 40.0	F (Fail)	0
Ab (Absent)	-	Ab (Absent)	0

Sd/-

Dr. Parag R. Gogate
BoS-Chairman-Chemical Engineering
Faculty of Technology

Sd/-

Dr. Deven Shah
Associate Dean
Faculty of Science & Technology

Sd/-

Prof. Shivram S. Garje
Dean
Faculty of Science & Technology