Applied Differential Calculus in Chemical Engineering			
Course Code	**1BMATCH301**	Scheme	2025
Type of Course	Applied Science Course (ASC)	Semester	III
Teaching Hours/Week (L:T:P)	42 (3:1:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	120 (42:28:0:50)	SEE Marks	50
Credits	**4**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

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

CO1: Apply Laplace transforms, Fourier series, Fourier transforms, and Z-transforms to solve differential equations, difference equations, and engineering problems involving continuous and discrete systems.

CO2: Analyze partial differential equations and variational problems by selecting appropriate numerical and analytical techniques, including finite difference methods and Euler's equation, to interpret engineering and physical phenomena.

MODULE-1: LAPLACE TRANSFORMS

Definition and Laplace transform of elementary functions (statements only). Problems on Laplace transform of $e^{at} f(t), t^n f(t), \frac{f(t)}{t}$. Laplace transforms of derivatives and integrals.

Laplace Transform of periodic functions (statement only) and unit-step function - Problems.

Inverse Laplace transforms: definition and problems. solution of differential equations.

Number of Hours: 8 hrs Theory + 3 hrs Tutorials

MODULE-2: FOURIER SERIES

Introduction to infinite series, convergence and divergence. Periodic functions, Dirichlet’s conditions. Fourier series of periodic functions with period 2π and arbitrary period. Complex Fourier series. Practical harmonic analysis.

Number of Hours: 8 hrs Theory + 3 hrs Tutorials

MODULE-3: FOURIER TRANSFORMS

Definition and problems on Fourier Transform. Fourier sine and cosine transforms - Problems. Inverse Fourier transform, Inverse Fourier cosine and sine transforms - Problems. Convolution theorem (only statement) - problems.

Number of Hours: 8 hrs Theory + 3 hrs Tutorials

MODULE-4: NUMERICAL SOLUTION OF PDE

Classification of second-order partial differential equations, finite difference approximation of derivatives. Solution of one-dimensional heat equation by Schmidt explicit formula and Crank-Nicholson method. Solution of one-dimensional wave equation using explicit three level formula and implicit scheme.

Number of Hours: 9 hrs Theory + 2 hrs Tutorials

MODULE-5: CALCULUS OF VARIATIONS AND Z-TRANSFORMS

Calculus of Variations: Definition, Variation of a functional, Euler’s equation, variational problems. Applications: Hanging cable problem, Brachistochrone problem.

Z-TRANSFORMS: Definition, Standard Z-transforms, damping rule, Shifting rule, Initial value and final value theorems-problems. Inverse Z-transform and applications to solve difference equations. **Number of Hours: 9 hrs Theory + 3 hrs Tutorials**

Suggested Learning Resources: (Textbook/ Reference Book/ Manuals):

Textbooks:

1. **B.S. Grewal**, *Higher Engineering Mathematics*, 45th Edition, Khanna Publishers.
2. **Erwin Kreyszig**, *Advanced Engineering Mathematics*, 10th Edition, Wiley India.

Reference books / Manuals:

3. B.V. Ramana: Higher Engineering Mathematics, McGraw-Hill Education, 11th Ed.
4. Srimanta Pal & Subodh C. Bhunia: Engineering Mathematics, Oxford University Press, 3rd Reprint, 2016.
5. N. P Bali and Manish Goyal: A textbook of Engineering Mathematics, Laxmi Publications.
6. C. Ray Wylie, Louis C. Barrett: Advanced Engineering Mathematics, McGraw Hill Book Co. New York, 6th Edition.
7. Gupta C.B, Sing S. R. and Mukesh Kumar: Engineering Mathematic for Semester I and II, Mc- Graw Hill Education (India) Pvt. Ltd 2015.
8. H. K. Dass and Er. Rajnish Verma: Higher Engineering Mathematics, S. Chand Publication (2014).
9. James Stewart: Calculus, Cengage publications, 7th edition, 4th Reprint 2019.

Web links and Video Lectures (e-Resources):

- http://www.class-central.com/subject/math(MOOCs)
- http://academicearth.org/
- http://www.bookstreet.in.
- VTU e-Shikshana Program
- VTU EDUSAT Program

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Flipped Classroom Approach**
   - Students review video lectures and reading materials before class.
   - Classroom sessions focus on problem-solving, discussions, and applications of transform techniques and optimization models.
2. **Problem-Based Learning (PBL)**
   - Real-world engineering problems involving Fourier Transforms, Z-Transforms, and Linear Programming are assigned for collaborative solution development.
3. **ICT-Enabled Teaching**
   - Use of MATLAB, Python, and online simulation tools to visualize transforms, optimization problems, and signal-processing applications.
4. **Collaborative Learning**
   Group assignments and mini-projects on optimization models and transform applications.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)**shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Assignment at RBL3 and RBL4 levels based on Teamwork (TW) activities.	10
2.	GATE-based Aptitude Test.	15

Rubrics **for Learning Activity–1: Assignment (10 Marks)**

Performance Indicator	**Superior (15)**	**Good (12)**	**Fair (10)**	**Needs Improvement (8)**
Quantitative Aptitude	≥90% correct responses	75–89% correct	60–74% correct	<60% correct
Analytical Thinking	Excellent logical reasoning and interpretation	Good reasoning ability	Moderate reasoning	Weak reasoning
Time Management	Completes all questions within allotted time	Completes most questions	Requires additional time	Unable to complete
Accuracy & Precision	Very high accuracy	Good accuracy	Moderate accuracy	Low accuracy

Rubrics for Learning Activity–2: GATE-Based Aptitude Test (15 Marks)

Performance Indicator	Superior (10)	Good (8)	Fair (6)	Needs Improvement (5)
Understanding of Concepts	Demonstrates excellent conceptual clarity and application	Good understanding with minor errors	Basic understanding	Poor understanding
Problem Solving Ability	Solves all problems correctly with proper methodology	Solves most problems correctly	Partial solutions with errors	Unable to solve problems effectively
Mathematical Accuracy	Calculations and derivations are error-free	Minor computational errors	Several errors	Significant errors
Presentation & Organization	Well-structured, neat, and professionally presented	Organized with minor deficiencies	Average presentation	Poor presentation

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Seminar on Fourier Series of periodic functions and harmonic analysis	6
2.	MATLAB/Python Simulation of Fourier and Z-Transform problems	6
3.	Mini Project on employing Numerical techniques in solving PDEs in Engineering Applications	6
4.	Case Study on Signal Processing using Transform Techniques	6
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Application of Fourier Series in signal representation and on harmonic analysis of periodic signals.	6
2.	Explore applications of Laplace, Fourier and Z-transforms in digital signal processing.	6
3.	Solve a set of differential equations using Laplace transforms and difference equations using Z-transforms	6
4.	Develop and solve two real-world PDE problems using numerical techniques	6
5.	Study industrial applications of Fourier series and assignment models	6

Continuous Internal Evaluation (CIE)

1. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
2. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
3. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
4. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

1. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
2. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
3. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

MECHANICAL OPERATIONS			
Course Code	1BCH302	Scheme	2025
Type of course	**IPCCC**	Semester	IV
Teaching Hours/Week (L:T:P)	3:0:1:0	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	42:0 :14: 0	SEE Marks	50
Credits	**04**	Total Marks	100
Type of Examination (IPCC):	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	03

Course outcome (Course Skill Set)

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

1. List different Standard Sieve Series, Equivalent Diameters and Screening equipment
2. Apply the forces and laws of size reduction to explain the working principle of size reduction equipment
3. Apply flow of fluids through solid beds for filtration in specific
4. Summarize different sampling techniques and solids conveying machinery
5. Explain principle of size separation in Magnetic, Electrostatic, Froth Floatation techniques
6. Comprehend the size enlargement techniques

Module-1

PARTICLE TECHNOLOGY: Particle shape, particle size, different ways of expression of particle size, shape factor, sphericity, particle size analysis, screens – ideal and actual screens, Differential and cumulative size analysis, effectiveness of screen, Specific surface of a mixture of particles, Number of particles in a mixture, standard screens, Industrial screening equipment, Motion of screen, Grizzly, Gyratory screen, Vibrating screen, Trommels.

Number of Hours:6

Module-2

SIZE REDUCTION: Introduction – types of forces used for comminution, Criteria for comminution, Characteristics of comminuted products, Laws of size reduction, Work Index, Energy utilization, methods of operating crushers – Free crushing, choke feeding, open circuit grinding, closed circuit grinding, wet and dry grinding, Equipment for size reduction – Classification of size reduction equipment, equipment – Blake jaw crusher, Gyratory crusher, Smooth roll crusher, Toothed roll crusher, impactor, Ball mill, Critical speed of ball mill, Cutters – Knife cutter.

Number of Hours:8

Module-3

FLOW OF FLUID PAST IMMERSED BODIES: Drag, Drag coefficient, Pressure drop – Kozeny-Carman equation, Blake-Plummer, Ergun equation, Fluidization, conditions for fluidization, Minimum fluidization velocity, Pneumatic conveying.

MOTION OF PARTICLES THROUGH FLUIDS: Mechanics of particle motion, Equation for one dimensional motion of particles through a fluid in gravitational and centrifugal field, Terminal velocity, drag coefficient, motion of spherical particles in Stoke's region, Newton's region, and Intermediate region, Criterion for settling regime, hindered settling, Modification of equation for hindered settling, Centrifugal separators, Cyclones and Hydro cyclones.

Number of Hours:10

Module-4

SEDIMENTATION: Batch settling test, Coe and Clevenger theory, Kynch theory, thickener design.

FILTRATION: Classification of filtration, Cake filtration, Clarification, batch and continuous filtration, Pressure and vacuum filtration, Constant rate filtration, Characteristics of filter media, Industrial filters, Sand filter, Filter press, Leaf filter, Rotary drum filter, Centrifugal filtration – Suspended batch centrifuge, Filter aids, Application of filter aids, Principles of cake filtration

Number of Hours:8

Module-5

AGITATION AND MIXING: Application of agitation, Agitation equipment, Types of impellers – Propellers, Paddles and Turbines, Flow patterns in agitated vessels, Prevention of swirling, Standard turbine design, Power correlation and power calculation, mixing of solids, Types of mixers –, Muller mixers, Mixing index, Ribbon blender, Internal screw mixer.

SAMPLING, STORAGE AND CONVEYING OF SOLIDS: Sampling of solids, Storage of solids, Open and closed storage, Bulk and bin storage, Conveyors – Belt conveyers, Chain conveyor, Apron conveyor, Bucket conveyor, Screw conveyor.

MISCELLANEOUS SEPARATION: Magnetic separation, Electrostatic separation, Jigging, Heavy media separation, Froth floatation process.

Number of Hours:10

PRACTICAL COMPONENTS OF IPCC

FIXED SET OF EXPERIMENTS

1. Ball mill
2. Batch sedimentation
3. Free settling
4. Drop weight crusher
5. Screen effectiveness
6. Sieve analysis
7. Jaw crusher
8. Leaf filter
9. Air elutriation
10. Grindability index
11. Gyratory crusher
12. Froth floatation

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Warren McCabe, Julian Smith, Peter Harriott, Unit Operations of Chemical Engineering, 7th Edition
2. Badger W.L. and Banchero J.T., "Introduction to Chemical Engineering", 3rdedn. Tata McGraw Hill International Edition, Singapore, 1999

Reference books / Manuals:

1. Brown G.G., et.al., "Unit Operations", 1st edn., CBS Publisher, New Delhi, 1995
2. Foust A.S., et.al., "Principles of Unit Operations", 3rd edn., John Wiley and Sons, New York, 1997
3. Coulson J.H. and Richardson J.F., "Coulson and Richardson's Chemical Engineering", Vol-II Particle Technology and Separation Process, 6thedn., Asian Books (p) Ltd., New Delhi, 1998

Web links and Video Lectures (e-Resources):

https://nptel.ac.in/courses/103107123

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. An appeal is made to the teachers to use alternative effective teaching methodology to inculcate an interest in the subject and its applications to solve societal & industrial problems.
2. Efforts may be made to use MOOC's, videos, recorded contents, presentations to induce curiosity, better understanding, and also higher levels of learning.
3. Activities to promote interest may be incorporated wherever possible

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks**.

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks**.
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

CIE Practical component:

The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks.

The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 10 marks. For laboratory test, the student is required to conduct one experiment.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested rubrics for Practical continuous assessment:

Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to the course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)

Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output (3)	Student will be able to run the program but not able to analyze the output (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		

4.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.		
2.		
3.		
4.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs 1.

(i) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Passing requirement in SEE

Table – ICs/IPCCs 1 Distribution of marks

Component	**Description**	**Marks**
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		
Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
	Subtotal	**10**
	Total	**25**

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

MOMENTUM TRANSFER			
Course Code	**1BCH303**	Scheme	2025
Type of Course	**PCC**	Semester	III
Teaching Hours/Week (L:T:P)	3:1:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42:14:0:0	SEE Marks	50
Credits	**04**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

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

1. Recall the concepts of fluid statics and dynamics and able to measure pressure difference.
2. Explain the fundamental equations of fluid flow.
3. Compare the various equations for incompressible and compressible fluids in conduits.
4. Demonstrate the knowledge fluid flow principles in various types of flow measurements, transportation and metering equipment of fluids using experimental techniques and application to industry.
5. Develop functional relationships using dimensional analysis and similitude to solve technical problems.
6. Design appropriate flow systems and flow measuring instruments.

Module-1

FLUID STATICS AND ITS APPLICATIONS: Concept of unit operations, Concept of momentum transfer, Nature of fluids and pressure concept, variation of pressure with height – hydrostatic equilibrium, Barometric equation, Measurement of fluid pressure –manometers, Continuous gravity decanter, Centrifugal decanter.

FLUID FLOW PHENOMENA: Type of fluids – shear stress and velocity gradient relation, Newtonian and non-

Newtonian fluids, Viscosity of gases and liquids. Types of flow – laminar and turbulent flow, Reynold's stress, Eddy viscosity. Flow in boundary layers, Reynolds number, and Boundary layer separation and wake formation.

Number of Hours:8

Module-2

BASIC EQUATIONS OF FLUID FLOW: Average velocity, Mass velocity, Continuity equation, Euler and Bernoulli equations Modified equations for real fluids with correction factors, Pump work in Bernoulli equation, Angular momentum equation.

FLOW OF INCOMPRESSIBLE FLUIDS IN CONDUITS AND THIN LAYERS: Laminar flow through circular and non-circular conduits, Hagen Poiseuille equation, Laminar flow of non-Newtonian liquids, turbulent flow in pipes and closed channels.

Number of Hours:8

Module-3

FLOW OF INCOMPRESSIBLE FLUIDS IN CONDUITS AND THIN LAYERS: Friction factor chart, friction from changes in velocity or direction, Form friction losses in Bernoulli equation, Flow of fluids in thin layers.

FLOW OF COMPRESSIBLE FLUIDS: Continuity equation, Concept of Mach number, Total energy balance, Velocity of sound, Ideal gas equations, Flow through variable-area conduits, Adiabatic frictional flow, Isothermal frictional flow (Elementary treatment only).

Number of Hours:10

Module-4

TRANSPORTATION AND METERING OF FLUIDS: Pipes, fittings and valves, Measurement of fluid and gas flow rates by venturi meter, orifice meter, rotameter and pitot tube, Elementary concept of target meter, vortex-shedding meters, turbine meters, positive displacement meters, magnetic meters, Coriolis meters and thermal meters, Flow through open channel-weirs and notches.

Number of Hours:8

Module-5

PUMPS: Performance and Characteristics of pumps-positive displacement and centrifugal pumps, Fans, compressors, and blowers.

DIMENSIONAL ANALYSIS: Dimensional homogeneity, Rayleigh's, and Buckingham Π- methods, Significance of different dimensionless numbers, Elementary treatment of similitude between model and prototype.

Number of Hours:8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Warren McCabe, Julian Smith, Peter Harriott, Unit Operations of Chemical Engineering, 7th Edition
2. R. K. Bansal, A Textbook of Fluid Mechanics, Laxmi Publications (P) Ltd., New Delhi

Reference books / Manuals:

1. Coulson J.H. and Richardson J.F., “Chemical Engineering”, Vol-I, 5^{th} edn., Asian Books (p) Ltd., New Delhi, 1998
2. Badger W.L. and Banchero J.T., “Introduction to Chemical Engineering”, Tata McGraw Hill, New York, 1997.
3. K L Kumar, Engineering Fluid Mechanics, S. Chand Publishing, 2008

Web links and Video Lectures (e-Resources):

https://www.khanacademy.org/science/physics/fluids/fluid-dynamics/v/fluids-part-8
https://www.youtube.com/watch?v=8YDTgjkGraQ
https://www.youtube.com/watch?v=v00g-tf6zLg
https://www.youtube.com/watch?v=omgfWh3Ny18
https://www.youtube.com/watch?v=3fpCyjUn-14
https://www.youtube.com/watch?v=QGVLPTWq2qQ
https://www.youtube.com/watch?v=2I6CceTV7Mc

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. An appeal is made to the teachers to use alternative effective teaching methodology to inculcate an interest in the subject and its applications to solve societal & industrial problems.
2. Efforts may be made to use MOOC’s, videos, recorded contents, presentations to induce curiosity, better understanding, and higher levels of learning.
3. Activities to promote interest may be incorporated wherever possible

Assessment Structure:

- The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.
- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
3.		
4.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
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Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
5.		

6.		
7.		
8.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
6.		
7.		
8.		
9.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

5. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
6. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
7. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
8. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

4. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
5. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
6. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

MOMENTUM TRANSFER			
Course Code	**1BCH303**	Scheme	2025
Type of Course	**PCC**	Semester	III
Teaching Hours/Week (L:T:P)	3:1:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42:14:0:0	SEE Marks	50
Credits	**04**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

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

7. Recall the concepts of fluid statics and dynamics and able to measure pressure difference.
8. Explain the fundamental equations of fluid flow.
9. Compare the various equations for incompressible and compressible fluids in conduits.
10. Demonstrate the knowledge fluid flow principles in various types of flow measurements, transportation and metering equipment of fluids using experimental techniques and application to industry.
11. Develop functional relationships using dimensional analysis and similitude to solve technical problems.
12. Design appropriate flow systems and flow measuring instruments.

Module-1

FLUID STATICS AND ITS APPLICATIONS: Concept of unit operations, Concept of momentum transfer, Nature of fluids and pressure concept, variation of pressure with height – hydrostatic equilibrium, Barometric equation, Measurement of fluid pressure –manometers, Continuous gravity decanter, Centrifugal decanter.

FLUID FLOW PHENOMENA: Type of fluids – shear stress and velocity gradient relation, Newtonian and non-
Newtonian fluids, Viscosity of gases and liquids. Types of flow – laminar and turbulent flow, Reynold's stress, Eddy viscosity. Flow in boundary layers, Reynolds number, and Boundary layer separation and wake formation.

Number of Hours:8

Module-2

BASIC EQUATIONS OF FLUID FLOW: Average velocity, Mass velocity, Continuity equation, Euler and Bernoulli equations Modified equations for real fluids with correction factors, Pump work in Bernoulli equation, Angular momentum equation.

FLOW OF INCOMPRESSIBLE FLUIDS IN CONDUITS AND THIN LAYERS: Laminar flow through circular and non-circular conduits, Hagen Poiseuille equation, Laminar flow of non-Newtonian liquids, turbulent flow in pipes and closed channels.

Number of Hours:8

Module-3

FLOW OF INCOMPRESSIBLE FLUIDS IN CONDUITS AND THIN LAYERS: Friction factor chart, friction from changes in velocity or direction, Form friction losses in Bernoulli equation, Flow of fluids in thin layers.

FLOW OF COMPRESSIBLE FLUIDS: Continuity equation, Concept of Mach number, Total energy balance, Velocity of sound, Ideal gas equations, Flow through variable-area conduits, Adiabatic frictional flow, Isothermal frictional flow (Elementary treatment only).

Number of Hours:10

Module-4

TRANSPORTATION AND METERING OF FLUIDS: Pipes, fittings and valves, Measurement of fluid and gas flow rates by venturi meter, orifice meter, rotameter and pitot tube, Elementary concept of target meter, vortex-shedding meters, turbine meters, positive displacement meters, magnetic meters, Coriolis meters and thermal meters, Flow through open channel-weirs and notches.

Number of Hours:8

Module-5

PUMPS: Performance and Characteristics of pumps-positive displacement and centrifugal pumps, Fans, compressors, and blowers.

DIMENSIONAL ANALYSIS: Dimensional homogeneity, Rayleigh's, and Buckingham Π- methods, Significance of
different dimensionless numbers, Elementary treatment of similitude between model and prototype.

Number of Hours:8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

3. Warren McCabe, Julian Smith, Peter Harriott, Unit Operations of Chemical Engineering, 7th Edition
4. R. K. Bansal, A Textbook of Fluid Mechanics, Laxmi Publications (P) Ltd., New Delhi

Reference books / Manuals:

4. Coulson J.H. and Richardson J.F., "Chemical Engineering", Vol-I, 5^{th} edn., Asian Books (p) Ltd., New Delhi, 1998
5. Badger W.L. and Banchero J.T., "Introduction to Chemical Engineering", Tata McGraw Hill, New York, 1997.
6. K L Kumar, Engineering Fluid Mechanics, S. Chand Publishing, 2008

Web links and Video Lectures (e-Resources):

https://www.khanacademy.org/science/physics/fluids/fluid-dynamics/v/fluids-part-8
https://www.youtube.com/watch?v=8YDTgjkGraQ
https://www.youtube.com/watch?v=v00g-tf6zLg
https://www.youtube.com/watch?v=omgfWh3Ny18
https://www.youtube.com/watch?v=3fpCyjUn-14
https://www.youtube.com/watch?v=QGVLPTWq2qQ
https://www.youtube.com/watch?v=2I6CceTV7Mc

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

4. An appeal is made to the teachers to use alternative effective teaching methodology to inculcate an interest in the subject and its applications to solve societal & industrial problems.
5. Efforts may be made to use MOOC's, videos, recorded contents, presentations to induce curiosity, better understanding, and higher levels of learning.
6. Activities to promote interest may be incorporated wherever possible

Assessment Structure:

- The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.
- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
5.		
6.		

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
9.		

10.		
11.		
12.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
10.		
11.		
12.		
13.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

9. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
10. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
11. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
12. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

7. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
8. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
9. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

PROCESS PRINCIPLES AND CALCULATIONS			
Course Code	**1BCH304**	Scheme	2025
Type of Course	**PCC**	Semester	III
Teaching Hours/Week (L:T:P)	2:1:0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	28:14:0:0	SEE Marks	50
Credits	**03**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	03

Course outcome (Course Skill Set)

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

13. Convert units from one system to others and to express composition of solids, liquids and gases.
14. Discuss material balance of steady state processes like distillation, absorption, extraction, crystallization.
15. Solve material balance problems like drying, mixing, evaporation, bypass, recycle and psychometry.
16. Discuss concepts of material balance problems with chemical reactions, combustions and air fuel calculation.
17. Explain the concepts of thermos physics and thermos chemistry and solve steady state enthalpy balance problems.
18. Develop mathematical solutions for mass and energy balance for any processes.

Module-1

UNITS AND DIMENSIONS: Fundamental and derived units, Conversion, Dimensional consistency of equations, Dimensionless groups and constants, conversions of equations.

BASIC CHEMICAL CALCULATIONS: Concept of mole, mole fraction, Compositions of mixtures of solids, liquids and gases, Concept of Normality, Molarity, Molality, ppm, Ideal gas law calculations. Hours: 5

Module-2

MATERIAL BALANCE WITHOUT REACTION: General material balance equation for steady and unsteady state, Typical steady state material balances in distillation, absorption, extraction. Hours: 5

Module-3

MATERIAL BALANCE WITHOUT REACTION contd.: Drying, mixing and evaporation, Elementary treatment of material balances involving bypass, recycle and purging. Hours: 5

Module-4

STEADY STATE MATERIAL BALANCE WITH REACTION: Principles of Stoichiometry, Concept of limiting, excess reactants and inert, fractional and percentage conversion, fractional yield and percentage yield, selectivity, related problems, Ultimate and proximate analysis of fuels, Calculations involving burning of solid, liquid and gaseous fuels, excess air, air-fuel ratio calculations. Hours: 7

Module-5

ENERGY BALANCE: General steady state energy balance equation, Thermo physics, Thermo chemistry and laws, Heat capacity, Enthalpy, Heat of formation, Heat of reaction, Heat of combustion and Calorific values. Heat of solution, Heat of mixing, Heat of crystallization, determination of ΔH_R at standard and elevated temperatures, Theoretical flame temperature and adiabatic flame temperature. Hours: 6

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Bhatt, B.L. and Vora, S.M., Stoichiometry (SI Units), Third Edition, 1996, Tata McGraw Hill Publishing, Ltd., New Delhi, 1996.
2. Hougen, O.A., Waston, K.M. and Ragatz, R.A., Chemical Process Principles Part –I, Material and Energy Balances, Second Edition, CBS publishers and distributors, New Delhi, 1995.
3. Himmelblau, D.M., Basic Principles and Calculations in Chemical Engineering, 6th Edition, Prentice Hall Of India, New Delhi, 1997.

<u>Reference books / Manuals:</u>

1. Richard M. Felder and Ronald W. Rousseau, Elementary Principles of Chemical Processes, John Wiley & Sons, 3rd Edition, 2005.

Web links and Video Lectures (e-Resources):

https://www.youtube.com/watch?v=bYW70-nsfGc&list=PL23LJMmRTn8fwtijrPEgIbqZAaKCc3oEg&index=6
https://www.youtube.com/watch?v=4EWmB9JVcBo&list=PL23LJMmRTn8fwtijrPEgIbqZAaKCc3oEg&index=4
https://www.youtube.com/watch?v=4EWmB9JVcBo
https://www.youtube.com/watch?v=s7J6R9wECh8
https://www.youtube.com/watch?v=LtSA06dy5MY

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

7. An appeal is made to the teachers to use alternative effective teaching methodology to inculcate an interest in the subject and its applications to solve societal & industrial problems.
8. Efforts may be made to use MOOC's, videos, recorded contents, presentations to induce curiosity, better understanding, and also higher levels of learning.
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- The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.
- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
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A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students**. These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
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Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

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Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to): - Course Project - Case Study Presentation - Programming Assignment - Tool/Software Exploration - Literature Review - Open Book Test (preferably at RBL4 and RBL5 levels) - GATE-based Aptitude Test - Assignment (at RBL3, RBL4, or RBL5 levels) - Any other relevant and innovative academic activity - Use of MOOCs and Online Platforms
Suggested Innovative Delivery Methods may include (but are not limited to): - Flipped Classroom - Problem-Based Learning (PBL) - Case-Based Teaching - Simulation and Virtual Labs - Partial Delivery of course by Industry expert/ industrial visits - ICT-Enabled Teaching - Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
13.		
14.		
15.		
16.	(Add rows if required)	
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
14.		
15.		
16.		
17.	(Add rows if required)	

Continuous Internal Evaluation (CIE)

13. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
14. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
15. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
16. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

10. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
11. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.
12. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

VI Semester

Materials Chemistry and its Applications			
Course Code	**1BCH305**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	2:0:0:2	SEE Marks	50
Total Hours of Pedagogy	42	Total Marks	100
Credits	03	Exam Hours	03

CO 1	Explain the principles of electrochemistry, electrochemical cells, batteries, fuel cells, and supercapacitors for energy conversion and storage applications. *(Understand – K2)*
CO 2	Describe polymerization mechanisms, molecular weight determination, thermal properties, and the synthesis, properties, and applications of engineering polymers and elastomers.
CO 3	Apply the principles and instrumentation of spectroscopic, chromatographic, and thermal analytical techniques for qualitative and quantitative chemical analysis.
CO 4	Analyze adsorption phenomena, catalytic processes, and green chemistry metrics to evaluate sustainable industrial chemical processes.
CO 5	Explain petroleum refining, specialty polymer additives, and industrial organic synthesis, including retrosynthetic approaches and pharmaceutical process chemistry for the manufacture of value-added chemicals.

Pedagogy (General Instructions)

These are sample Strategies, which teacher can use to accelerate the attainment of the various course outcomes.

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1. Lecturer method (L) does not mean only traditional lecture method, but different type of teaching methods may be adopted to develop the outcomes.
2. Show Video/animation films to convince abstract concepts.
4. Encourage collaborative (Group Learning) Learning in the class
5. Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes critical thinking
6. Adopt Problem Based Learning (PBL), which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
7. Topics will be introduced in a multiple representation.
8. Show the different ways to solve the same problem and encourage the students to come up with their own creative ways to solve them.
9. Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.

Module-1 Electrochemistry and Energy Storage Systems (9 Hours)

Fundamental Principles: Review of electrode potentials, Nernst equation for single electrode potential, numerical. Reference electrodes (Standard Hydrogen Electrode, Calomel electrode), and electrochemical cells. **Batteries:** Classification and working mechanisms of primary and secondary batteries (Zinc-air, Lithium-ion, and Sodium-ion batteries). **Fuel Cells:** Introduction, design, and working principles of Proton Exchange Membrane Fuel Cells (PEMFC) and Solid Oxide Fuel Cells (SOFC). **Supercapacitors:** Principles of electrical double-layer capacitors (EDLCs) and pseudo capacitors; application in energy harvesting and storage systems

Pedagogy	**Chalk and talk/power point presentation: Fundamental Principles:** Definition of electrode potential, derivation of Nerst equation from Gibbs equation, numerical. Reference electrodes – 1° and 2°, definition and types of electrochemcial cells. **Batteries**: Classification as 1°, 2° and reserve with examples. Principle, construction and Working mechanism of Zinc-air, Lithium-ion, and Sodium-ion batteries. Fuel cell: Introduction, differences with conventional cell. Construction and working of Proton Exchange Membrane Fuel Cells (PEMFC): H_2-O_2 fuel cell and SOFC. **Videos/Learning material:** Working principles of Zinc-air, Lithium-ion, Sodium-ion batteries, Proton Exchange Membrane Fuel Cells (PEMFC): H_2-O_2 fuel cell and SOFC **Self-study:** Lead-acid batteries, flexible supercapacitors.

Module-2 Polymer Science and Advanced Engineering Materials (8 Hours)

Polymerization Mechanisms: Addition and condensation polymerization; kinetics of step-growth and chain-growth polymerization. **Molecular Weight & Thermal Properties:** Number-average and weight-average molecular weights, polydispersity index (PDI), numerical. Glass transition temperature (T_g), and melting temperature (T_m). **Engineering Plastics & Elastomers:** Synthesis, properties, and applications of thermoplastics (Nylon, Teflon, Polycarbonates), thermosets (Epoxy resins, Bakelite), and elastomers (Buna-S, Neoprene).

Pedagogy	**Chalk and talk/power point presentation**: **Polymerization Mechanisms** - Introduction to Polymers and classification based on the mechanism of polymerization. Definition of Number-average and weight-average molecular weights, polydispersity index (PDI) and based numerical. Definitionand importanceof T_g and T_m. **Engineering Plastics & Elastomers –** Synthesis of Nylon, Teflon, Polycarbonates, epoxy resins, Bakelite , Buna-S and Neoprene with chemical equations and applications. **Videos/Learning material**: Mechanism of polymerization, T_g and T_m. **Self-study:** Kevlar synthesis and applications.

Module-3 Instrumental Methods of Chemical Analysis (8 Hours)

- **Spectroscopic Techniques:** Principles, instrumentation, and chemical applications of UV-Visible spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and Nuclear Magnetic Resonance (NMR) spectroscopy. **Chromatographic Separations:** Theoretical foundations and industrial applications of Gas Chromatography (GC) and High-Performance Liquid Chromatography (HPLC). **Thermal Analysis:** Principles and applications of Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Differential Thermal Analysis (DTA) in materials characterization.

Pedagogy	**Chalk and talk/power point presentation**: **Spectroscopic Techniques -** Principles, instrumentation, and chemical applications of UV-Visible spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and Nuclear Magnetic Resonance (NMR) spectroscopy **Videos/Learning material:** industrial applications of Gas Chromatography (GC) and High-Performance Liquid Chromatography (HPLC). applications of Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), and Differential Thermal Analysis (DTA) in materials characterization **Self-study:** Supplementary numerical.

Module-4 Surface Chemistry, Catalysis, and Green Processes (9 Hours)

Adsorption Phenomena: Physical adsorption vs. chemisorption, adsorption isotherms (Langmuir and Freundlich models), and BET surface area determination. **Industrial Catalytic Processes:** Catalytic cracking, reforming, hydrogenation, oxidation, and polymerization in petroleum and petrochemical industries. **Green Chemistry Metrics:** Principles of green chemistry, atom economy, E-factor, and the design of sustainable chemical synthesis routes.

Pedagogy	**Chalk and talk/power point presentation:** PIntroduction and differences between physisorption and chemisorption. Principle, instrumentation of BET. Principles of green chemistry, atom economy, E-factor, and the design of sustainable chemical synthesis routes. **Videos/Learning material**: Catalytic cracking, reforming, hydrogenation, oxidation, and polymerization in petroleum and petrochemical industries. **Self-study:** Bomb calorimetry for GCV and NCV determination.

Module-5 Industrial Organic Synthesis and Specialty Chemicals (8 Hours)

Petroleum Refining & Petrochemicals: Fractional distillation of crude oil, cracking, reforming, and the synthesis of foundational petrochemical building blocks (ethylene, propylene, butadiene, and benzene). **Specialty Polymers and Additives:** Synthesis and formulation of plasticizers, antioxidants, UV stabilizers, and flame retardants.**Fine Chemicals and Pharmaceuticals:** Introduction to multi-step organic synthesis, retrosynthetic analysis, and process chemistry for active pharmaceutical ingredients (APIs).

Pedagogy	**Videos/Learning material**: Fractional distillation of crude oil, cracking, reforming, and the synthesis of foundational petrochemical building blocks (ethylene, propylene, butadiene, and benzene). Synthesis and formulation of plasticizers, antioxidants, UV stabilizers, and flame retardants. Introduction to multi-step organic synthesis, retrosynthetic analysis, and process chemistry for active pharmaceutical ingredients (APIs). **Self-study:** Knocking, diesel knocking and antiknocks.

Course outcome (Course Skill Set)	
At the end of the course the student will be able to:	
CO 1	Explain the principles of electrochemistry, electrochemical cells, batteries, fuel cells, and supercapacitors for energy conversion and storage applications. *(Understand – K2)*
CO 2	Describe polymerization mechanisms, molecular weight determination, thermal properties, and the synthesis, properties, and applications of engineering polymers and elastomers.
CO 3	Apply the principles and instrumentation of spectroscopic, chromatographic, and thermal analytical techniques for qualitative and quantitative chemical analysis.
CO 4	Analyze adsorption phenomena, catalytic processes, and green chemistry metrics to evaluate sustainable industrial chemical processes.
CO 5	Explain petroleum refining, specialty polymer additives, and industrial organic synthesis, including retrosynthetic approaches and pharmaceutical process chemistry for the manufacture of value-added chemicals.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50) in the semester-end examination (SEE).

Continuous Internal Evaluation:

Three Unit Tests each of 20 Marks (duration 01 hour)

1. First test at the end of 5thweek of the semester
2. Second test at the end of the 10thweek of the semester
3. Third test at the end of the 15th week of the semester

Two assignments each of 10 Marks

4. First assignment at the end of 4th week of the semester
5. Second assignment at the end of 9th week of the semester Group discussion/Seminar/quiz any one of three suitably planned to attain the COs and POs for **20 Marks (duration 01 hours)**
6. At the end of the 13thweek of the semester The sum of three tests, two assignments, and quiz/seminar/group discussion will be out of 100 marks and will be scaled down to 50 marks (to have less stressed CIE, the portion of the syllabus should not be common /repeated for any of the methods of the CIE. Each method of CIE should have a different syllabus portion of the course).

CIE methods /question paper is designed to attain the different levels of Bloom’s taxonomy as per the outcome defined for the course.

Semester End Examination:

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (duration 03 hours)

1. The question paper will have ten questions. **Each question is set for 20 marks**.
2. There will be **2 questions from each module**. Each of the two questions under a module (with a maximum of 3 sub-questions), should have a mix of topics under that module. The students have to answer 5 full questions, selecting one full question from each module.

Suggested Learning Resources:

Books

1. P. C. Jain and Monica Jain, Engineering Chemistry, 17th ed., Dhanpat Rai Publishing Company, New Delhi, 2018.
2. B. Sivasankar, Engineering Chemistry, 3rd ed., McGraw Hill Education (India) Pvt. Ltd., New Delhi, 2019.
3. Allen J. Bard and Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd ed., John Wiley & Sons, New York, 2001.
4. Ryan O'Hayre, Suk-Won Cha, Whitney Colella, and Fritz B. Prinz, Fuel Cell Fundamentals, 3rd ed., John Wiley & Sons, Hoboken, 2016.
5. George Odian, Principles of Polymerization, 4th ed., John Wiley & Sons, Hoboken, 2004.
6. Robert J. Young and Peter A. Lovell, Introduction to Polymers, 3rd ed., CRC Press, Boca Raton, 2011.
7. Douglas A. Skoog, F. James Holler, and Stanley R. Crouch, Principles of Instrumental Analysis, 7th ed., Cengage Learning, Boston, 2018.
8. Gurdeep R. Chatwal and Sham K. Anand, Instrumental Methods of Chemical Analysis, 5th ed., Himalaya Publishing House, Mumbai, 2009.

9. Peter Atkins and Julio de Paula, Atkins' Physical Chemistry, 11th ed., Oxford University Press, Oxford, 2018.
10. Jonathan Clayden, Nick Greeves, and Stuart Warren, Organic Chemistry, 2nd ed., Oxford University Press, Oxford, 2012.

Web links and Video Lectures (e-Resources):

MIT OpenCourseWare – Chemistry and Materials Science

- https://ocw.mit.edu/
- (Free lecture notes and video lectures on electrochemistry, polymers, spectroscopy, and materials science.)

NPTEL (National Programme on Technology Enhanced Learning)

- https://nptel.ac.in/
- (Comprehensive video lectures by IIT faculty on Engineering Chemistry, Electrochemistry, Polymer Science, Instrumental Analysis, Surface Chemistry, and Green Chemistry.)

SWAYAM

- https://swayam.gov.in/
- (MOOCs on Engineering Chemistry, Materials Science, Energy Storage Systems, and Green Technologies.)

Royal Society of Chemistry (RSC) – Learn Chemistry

- https://edu.rsc.org/
- (Educational resources, articles, experiments, and teaching materials covering electrochemistry, polymers, spectroscopy, catalysis, and green chemistry.)

Khan Academy – Chemistry

- https://www.khanacademy.org/science/chemistry
- (Free video lectures and tutorials on physical chemistry, organic chemistry, chemical bonding, spectroscopy, and related fundamentals.)

1.

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

- **Daniell Cell (Electrochemical Cell) – Practical Demonstration**
  Activity: Construction and working of a Daniell cell; measurement of EMF.
  Video: https://www.youtube.com/results?search_query=Daniell+cell+experiment+practical

- **FTIR Spectroscopy – Instrumentation and Sample Analysis**
  Activity: Interpretation of FTIR spectra and identification of functional groups.
  Video: https://www.youtube.com/results?search_query=FTIR+spectroscopy+practical

- **HPLC/GC Demonstration**
  Activity: Separation and analysis of mixtures using chromatographic techniques.
  Video: https://www.youtube.com/results?search_query=HPLC+instrument+working+practical

- **Hydrogen Fuel Cell Working Demonstration**
  Activity: Understanding PEM fuel cell operation and electrochemical energy conversion.
  Video: https://www.youtube.com/results?search_query=hydrogen+fuel+cell+working+demonstration

- **Petroleum Refining Laboratory / Fractional Distillation Demonstration**
  Activity: Study of crude oil refining, fractional distillation, and refinery processes.
  Video: https://www.youtube.com/results?search_query=petroleum+refining+laboratory+fractional+distillation

Momentum Transfer Lab (Professional Core Course Lab)		Scheme	2025
Course Code	1BCHL306	Semester	III
Teaching Hours/Week (L:T:P)	0:0:1:0	CIE Marks	50
Total Hours of Pedagogy L:T:P:SLTW	0:0:14:0	SEE Marks	50
Credits	01	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	03

Course outcome (Course Skill Set)

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

1. Measure and analyze frictional losses, flow behavior, and pressure drop in circular, non-circular, helical pipes, and pipe fittings.
2. Evaluate the performance of flow measurement devices such as Venturi meters, orifice meters, and notches for incompressible fluid flow systems.
3. Analyze fluid flow through packed beds, fluidized beds, and unsteady flow systems such as tank emptying operations.
4. Demonstrate and interpret fundamental fluid mechanics principles including Bernoulli's theorem and Reynolds experiment.
5. Determine and compare the operating characteristics and performance of centrifugal and positive displacement pumps.

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **70 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **30 marks.**
4. For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
FIXED SET OF EXPERIMENTS

1. Friction in circular pipes.
2. Flow measurement using Venturi /orifice meters (incompressible fluid).
3. Flow over notches.
4. Packed bed.
5. Study of characteristics for centrifugal, Positive displacement pump
6. Reynolds apparatus

PART – B
OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Fluidized bed.
2. Study of various pipe fittings and their equivalent lengths.
3. Unsteady Flows-Emptying of Tank
4. Friction in helical/spiral coils.
5. Friction in non-circular pipes.
6. Bernoulli's Experiment.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

5. Warren McCabe, Julian Smith, Peter Harriott, Unit Operations of Chemical Engineering, 7th Edition
6. R. K. Bansal, A Textbook of Fluid Mechanics, Laxmi Publications (P) Ltd., New Delhi

Reference books / Manuals:

7. Coulson J.H. and Richardson J.F., "Chemical Engineering", Vol-I, 5th edn., Asian Books (p) Ltd., New Delhi, 1998
8. Badger W.L. and Banchero J.T., "Introduction to Chemical Engineering", Tata McGraw Hill, New York, 1997.
9. K L Kumar, Engineering Fluid Mechanics, S. Chand Publishing, 2008

Web links and Video Lectures (e-Resources):

https://vlabs.iitkgp.ac.in/fml/

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Virtual labs
2. Project based learning

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for **30 marks.** Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to **20 marks**. Final average of marks for report and test shall be out of 50 marks.

For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Basics of Simulation Lab			
Course Code	**1BCHL307A**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	III
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

7. Perform process simulations using DWSIM software tool for chemical engineering applications.
8. Analyse simulation results to determine the behaviour and characteristics of unit operations.
9. Interpret simulation data and relate the results to underlying engineering principles.
10. Record, organize, and communicate simulation procedures, observations, and outcomes in a professional manner.

SET OF EXPERIMENTS

1. Simulation of Pumps
2. Simulation of mixer operation
3. Simulation of heater
4. Simulation of cooler
5. Simulation of compressor
6. Simulation of flash separator
7. Simulation of short cut distillation
8. Generation of T-XY diagram for different ideal binary component systems
9. Generation of P-XY diagram for different ideal binary component systems
10. Thermodynamic Analysis for different ideal binary component systems
11. Simulation of conversion reactor
12. Simulation of equilibrium reactor

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

7. **Amiya K. Jana, "Chemical Process Modelling and Computer Simulation", 2nd Edition, PHI Learning Pvt Ltd, 2011, New Delhi.**
8. **Dominic C.Y. Foo and Mainil Syamdani, "Chemical Engineering Process Simulation", 2nd Edition, Elsevier, 2022, United States.**

Reference books / Manuals:

1. **Ashok Kumar Verma, "Process Modelling and Simulation in Chemical, Biochemical and Environmental Engineering",2025, Springer Nature, Germany .**
2. **K. V. Narayanan and B. Lakshmikutty Stoichiometry and Process Calculations, 2nd edition, 2009, PHI Learning Private Ltd. New Delhi.**

Web links and Video Lectures (e-Resources):
Teaching-Learning Process (Innovative Delivery Methods): The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. 1. NPTEL and other videos for theory topics 2. ICT-Enabled Teaching. 3. Activity based learning. 4. Keep fundamentals as the core teaching content. 5. Present recent trends as short "industry snapshot" segments at the end of each module (e.g., 15–20 minutes), not as examinable depth topics. 6. Use case studies, videos, or demonstrations for the advanced concepts so students see applications without getting bogged down in mechanisms.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Solving Chemical Engineering Problems with MATLAB			
Course Code	1BCHL307B	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	III
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

11. Develop MATLAB programs for solving fundamental chemical engineering calculations.
12. Interpret simulation results through graphical visualization
13. Record, organize, and communicate simulation procedures, observations, and outcomes in a professional manner.

SET OF EXPERIMENTS

13. MATLAB program on variables, arrays, and mathematical operations.
14. MATLAB program on conditional statements and loops.
15. Engineering Data Visualization 2D and 3D plotting and Curve fitting.
16. Steady-State Heat Conduction through Composite walls, cylinder and sphere.
17. Transient Heating/Cooling using Lumped Parameter Analysis
18. Heat Exchanger Analysis to determine effectiveness and outlet temperatures using LMTD and NTU method.
19. Calculate the Humidity ratio, Relative humidity, Adiabatic saturation temperature and plot the Psychrometric relationships.
20. Drying Rate Curve Analysis to evaluate constant-rate period, falling-rate period, and drying time.
21. Use MATLAB for Adsorption Isotherm Modeling.
22. VLE of Ideal Binary Mixtures using Raoult's Law.
23. Activity Coefficient Calculation for non-ideal solutions using suitable model.
24. MATLAB program to determine settling velocity using stokes law and Intermediate region correlations.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

9. Steven C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientists, 3rd Edition, McGraw Hill, 2012.

Reference books / Manuals:

10.

Web links and Video Lectures (e-Resources):

1. https://onlinecourses.nptel.ac.in/e-learning/preview/noc20_ge05
2. https://www.udemy.com/course/computational-physics
3. https://onlinecourses.nptel.ac.in/e-learning/preview/noc24_ph36

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

7. NPTEL and other videos for theory topics
8. ICT-Enabled Teaching.
9. Activity based learning.
10. Keep fundamentals as the core teaching content.
11. Present recent trends as short "industry snapshot" segments at the end of each module (e.g., 15–20 minutes), not as examinable depth topics.
12. Use case studies, videos, or demonstrations for the advanced concepts so students see applications without getting bogged down in mechanisms.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Using Python Programming for Chemical Engineering			
Course Code	**1BCHL307C**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	III
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

CO1: Comprehend the Python and MATLAB programming concepts.

CO2: Apply Python and MATLAB programming concepts to solve engineering problems.

CO3: Develop computational models for chemical engineering systems.

CO4: Analyze the behavior of developed mathematical models using appropriate computational tool.

CO5: Employ self-learning strategies to explore and utilize advanced PYTHON techniques for addressing evolving engineering challenges.

SET OF EXPERIMENTS

25. Introduction to python program and tools with its function.
26. Programs using conditional statements, functions, loops, and arrays.
27. Program for the solution of linear algebraic equations
28. Programs for plotting and visualization of data
29. Program to solve for pressure drop in a pipe
30. Program to solve ordinary differential equation using Range-Kutta method
31. Program to generate the TXY and PXY plots for ideal mixtures.
32. Program to solve for minimum fluidization velocity
33. Program to calculate the molar volume using equation of state
34. Program to develop characteristic curves for centrifugal pump
35. Program to solve for friction factor in circular and non-circular pipe
36. Program to model and estimate composition for a multicomponent flash system

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

11. **Ahuja, P. (2010). Introduction to Numerical Methods in Chemical Engineering, (1st ed.). New Delhi, India: PHI Learning Private Limited, India.**
12. **Reema Thareja (2025). Python Programming: Using Problem-Solving Approach (3rd ed.). New Delhi, India: Oxford University Press India.**

Reference books / Manuals:

3. **Heys, J. J. (2017). Chemical and Biomedical Engineering Calculations Using Python. Hoboken, NJ: John Wiley & Sons.**

Web links and Video Lectures (e-Resources):

2. **https://www.udemy.com/course/computational-physics**

3. **https://onlinecourses.nptel.ac.in/e-learning/preview/noc24_ph36**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

13. NPTEL and other videos for theory topics
14. ICT-Enabled Teaching.
15. Activity based learning.
16. Keep fundamentals as the core teaching content.
17. Present recent trends as short "industry snapshot" segments at the end of each module (e.g., 15–20 minutes), not as examinable depth topics.
18. Use case studies, videos, or demonstrations for the advanced concepts so students see applications without getting bogged down in mechanisms.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**

Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
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Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Understanding Equipment Design and Data Sheet Application			
Course Code	1BCHL307D	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	III
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

14. Explain the basic principles and concepts involved in equipment design.
15. Identify the types of industrial equipment and their applications.
16. Interpret equipment design parameters, specifications, and operating conditions.
17. Read and understand technical equipment data sheets, drawings, and specifications.
18. Evaluate key design parameters such as pressure, temperature, flow rate, capacity, materials, and dimensions.

SET OF EXPERIMENTS

37. **Flowsheet Symbols**: Drawing basic block and process flow diagrams.
38. **Piping Components**: Identifying valves, fittings, and basic line schedules.
39. **Flow Meter Selection**: Filling data sheets for orifice and venturi meters.
40. **Pump Curves**: Reading head-capacity graphs to fill basic sheets.
41. **Gasket Selection**: Choosing joint materials from standard vendor catalogs.
42. **Safety Valve Data Sheets**: Recording set pressure, fluid phase, and discharge data.
43. **Agitator Specification Sheets**: Recording impeller type, RPM, and motor power requirements.
44. **Storage Tank Data Sheets**: Entering operating capacity, design volume, and structural dimensions.
45. **Fittings & Flange Data**: Extracting dimensions and pressure-temperature ratings from vendor catalogs.
46. **Flow Meter Data Sheets**: Entering fluid density, viscosity, and flow ranges for orifice plates.
47. **Pipe Insulation Sizing**: Calculating insulation thickness using thermal data charts.
48. **Material of Construction**: Selecting basic metals using simple corrosion charts.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

13. M. V. Joshi and V. V. Mahajani, “Process Equipment Design”, Macmillan Publishers, 2009, India.
14. Suresh C. Maidargi, “Chemical Process Equipment: Design and Drawing”, Vol 1, PHI Learning, 2012, India.

Reference books / Manuals:

4. Gavin Towler, Ray Sinnott, “Chemical Engineering Design”, Elsevier Science, 2007.

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

19. NPTEL and other videos for theory topics
20. ICT-Enabled Teaching.
21. Activity based learning.
22. Keep fundamentals as the core teaching content.
23. Present recent trends as short "industry snapshot" segments at the end of each module (e.g., 15–20 minutes), not as examinable depth topics.
24. Use case studies, videos, or demonstrations for the advanced concepts so students see applications without getting bogged down in mechanisms.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
…					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	Excellent	Very Good	Good	Satisfactory
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)

Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Probability and Statistics for Chemical Engineering			
Course Code	**1BMATCH401**	Scheme	2025
Type of Course	Applied Science Course (ASC)	Semester	IV
Teaching Hours/Week (L:T:P)	42 (3:0:0)	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	90 (42:0:0:48)	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

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

CO1: Apply statistical and probabilistic techniques, including curve fitting, probability distributions, joint probability, Markov chains, estimation, hypothesis testing, and experimental design to solve engineering and data-driven problems.

CO2: Analyze statistical data using appropriate inferential methods, analysis of variance (ANOVA), correlation, regression, and design of experiments to draw valid conclusions and support engineering decision-making.

MODULE-1: STATISTICS AND PROBABILITY

Curve fitting: Principle of least squares, fitting a straight line, fitting of a parabola, fitting of the exponential curve of the $y = ab^x$. Correlation and Regression.

Probability distributions: Discrete distribution - Poisson distribution. Continuous distribution- Normal distribution.

Number of Hours: 8 hrs Theory

MODULE-2: JOINT PROBABILTY AND MARKOV CHAIN

Joint Probability Distributions: Discrete random variables, Mathematical expectations, Covariance and Correlation.

Markov Chain: Markov Chain, Probability vectors, stochastic matrices, fixed point vector, regular stochastic matrices. Higher transition probabilities, stationary distribution of regular Markov chain.

Number of Hours: 8 hrs Theory

MODULE-3: STATISTICAL INFERENCE – I

Introduction, estimation - point, interval; procedure for testing of hypothesis, level of significance, construction of confidence interval.

[Large sample] Test of significance for single mean, difference between two means, single proportion, difference between two proportions, and difference of two Standard deviations.

Number of Hours: 8 hrs Theory

MODULE-4: STATISTICAL INFERENCE – II

[Small sample] Test of significance for single mean, difference between two means, paired t-test, ratio of variances (F- distribution), Chi -Square distribution-goodness of fit, independence of attributes. Analysis of variance (one-way and two-way classifications).

Number of Hours: 9 hrs Theory

MODULE-5: DESIGN OF EXPERIMENTS
Principles of experimental design - Randomization, Replication, Local Control. Randomized block design, Completely Randomized block design, Latin Square Design - Problems.
Number of Hours: 9 hrs Theory

Suggested Learning Resources: (Textbook/ Reference Book/ Manuals):

Textbooks:

1. *Higher Engineering Mathematics*, **B.S. Grewal**, 45th Edition, Khanna Publishers.
2. Fundamentals of Biostatistics, **Khirfan A. Khan, Atiya Khanum,** 3rd edition, 2012, Ukaaz Publications.
3. An Introduction to Biostatistics, **P. S. S. Sundar Rao and J. Richard**, 4th edition, 2006, Prentice Hall of India.
4. Probability, Schaum's Outline Series, **Seymour Lipschutz and Marc Lars Lipson**, Second edition, 2011.

Reference books / Manuals:

5. B.V. Ramana: Higher Engineering Mathematics, McGraw-Hill Education, 11th Ed.
6. Srimanta Pal & Subodh C. Bhunia: Engineering Mathematics, Oxford University Press, 3rd Reprint, 2016.
7. Applied Statistics and Probability for Engineers, Douglas C. Montgomery, George C. Runger, 6th edition, Wiley.
8. Biostatistics, P. N. Arora, P. K. Malhan, 2nd edition, 2013, Himalaya Publishing House

Web links and Video Lectures (e-Resources):

- https://www.coursera.org/learn/basic-statistics
- https://www.coursera.org/learn/probability-intro
- https://www.classcentral.com/course/udacity-intro-to-statistics-361
- http://wiki.stat.ucla.edu/socr/index.php/Probability_and_statistics_EBook
- http://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statisticsspring-2014/
- http://nptel.ac.in/courses/*111105041/1* NPTEL >> Mathematics >> Probability and Statistics
- https:// www.khanacademy.org/Math
- https:// www.class-central.com/subject/math (MOOCS).

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. **Flipped Classroom Approach**
   - Students review video lectures and reading materials before class.
   - Classroom sessions focus on problem-solving, discussions, and applications of transform techniques and optimization models.
2. **Problem-Based Learning (PBL)**
   - Real-world engineering problems involving Fourier Transforms, Z-Transforms, and Linear Programming are assigned for collaborative solution development.
3. **ICT-Enabled Teaching**
   - Use of MATLAB, Python, and online simulation tools to visualize transforms, optimization problems, and signal-processing applications.

4. **Collaborative Learning**
   Group assignments and mini-projects on optimization models and transform applications.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks.**

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)**shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Assignment at RBL3 and RBL4 levels based on Teamwork (TW) activities.	10
2.	GATE-based Aptitude Test.	15

Rubrics **for Learning Activity–1: Assignment (10 Marks)**

Performance Indicator	**Superior (15)**	**Good (12)**	**Fair (10)**	**Needs Improvement (8)**
Quantitative Aptitude	≥90% correct responses	75–89% correct	60–74% correct	<60% correct
Analytical Thinking	Excellent logical reasoning and interpretation	Good reasoning ability	Moderate reasoning	Weak reasoning
Time Management	Completes all questions within allotted time	Completes most questions	Requires additional time	Unable to complete
Accuracy & Precision	Very high accuracy	Good accuracy	Moderate accuracy	Low accuracy

Rubrics for Learning Activity–2: GATE-Based Aptitude Test (15 Marks)

Performance Indicator	Superior (10)	Good (8)	Fair (6)	Needs Improvement (5)
Understanding of Concepts	Demonstrates excellent conceptual clarity and application	Good understanding with minor errors	Basic understanding	Poor understanding
Problem Solving Ability	Solves all problems correctly with proper methodology	Solves most problems correctly	Partial solutions with errors	Unable to solve problems effectively
Mathematical Accuracy	Calculations and derivations are error-free	Minor computational errors	Several errors	Significant errors
Presentation & Organization	Well-structured, neat, and professionally presented	Organized with minor deficiencies	Average presentation	Poor presentation

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Seminar on Probability, Statistics and Sampling Distribution concepts	6
2.	MATLAB/Python computations for the problems related to Probability, Statistics and Sampling Distribution concepts.	6
3.	Course Project on sampling distribution for testing of hypothesis.	6
4.	Case Study on testing hypothesis for large and small samples	6
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	Application of Probability, Statistics and Sampling Distribution concepts.	6
2.	Explore the real-life problems related to Probability, Statistics and Sampling Distribution concepts	6
3.	Solve a set of problems on Probability, Statistics and Sampling Distribution concepts.	6
4.	Develop and solve two real-world sampling distribution and design of experiment problems	6
5.	Study industrial applications of statistics, probability, sampling distributions and design of experiments.	6

Continuous Internal Evaluation (CIE)

1. The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
2. Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
3. The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
4. A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

1. For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
2. For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks.

3. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Heat Transfer			
Course Code	1BCH402	Scheme	2025
Type of course	**IPCC**	Semester	IV
Teaching Hours/Week (L:T:P)	42: 0 : 28	CIE Marks	50
Total Hours of Pedagogy L:T:P:SL:TW	42: 0: 28: 48	SEE Marks	50
Credits	**4**	Total Marks	100
Type of Examination (IPCC):	Theory- CIE +SEE, and Lab- CIE only.	Exam Hours	3

Course outcome (Course Skill Set)

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

1. Comprehend basic laws of heat transfer & derive steady state expression for determination of temperature distribution and heat conduction in different geometries
2. Determine critical thickness of insulation and efficiency of extended surfaces
3. Ddetermine LMTD, overall heat transfer coefficient & temperature distribution under unsteady-state heat conduction
4. Establish the analogy between momentum and heat transfer and describe pool boiling regimes.
5. Explain construction and working principle of heat exchangers and concepts of radiation
6. Comprehend significance of Dimensionless numbers in heat transfer coefficient calculation, heat transfer equipment design to explain working principle of evaporators

Module-1

INTRODUCTION: Various modes of heat transfer Viz. Conduction, Convection and Radiation.

CONDUCTION: Fourier's law, Steady state unidirectional heat flow through single and multiphase layer slabs, cylinders,
and spheres for constant and variable thermal conductivity.

INSULATION: Properties of insulation materials, Types of insulation, Critical and Optimum thickness.

Number of Hours: 10

Module-2

EXTENDED SURFACES: Fins – Types of fins, Derivation of fin efficiency for longitudinal fins, Fin effectiveness,
Elementary treatment of unsteady state heat conduction.

CONVECTION: Individual and overall heat transfer coefficient, LMTD, LMTD correction factor, Dimensionless numbers, Dimensional analysis, Empirical correlation for forced and natural convection.

Module-3

ANALOGY: Analogy between momentum and heat transfer- Reynolds, Colburn and Prandtl analogies.

HEAT TRANSFER WITH PHASE CHANGE: Boiling phenomena, Nucleate and Film boiling, Condensation - Film
and dropwise condensation.

HEAT TRANSFER EQUIPMENT: Double pipe heat exchangers, Shell and tube heat exchangers – Types of shell and
tube heat exchangers, Construction details, Condenser, types of condensers

Number of Hours:10

Module-4

DESIGN OF HEAT TRANSFER EQUIPMENT: Elementary design of double pipe heat exchanger, shell and tube heat exchanger and condensers. Numerical Problems.

Number of Hours: 12

Module-5

EVAPORATORS: Types of evaporators, performance of tubular evaporator – Evaporator capacity, Evaporator economy,
Multiple effect evaporator – Methods of feeding, effect of liquid head and boiling point elevation.
RADIATION: Properties and definitions, Absorptivity, Reflectivity, Emissive power and intensity of radiation, Black body radiation, Gray body radiation, Stefen – Boltzmann law, Wein's displacement law, Kirchhoff's law.

Number of Hours:10

PRACTICAL COMPONENTS OF IPCC

PART – A: FIXED SET OF EXPERIMENTS

1. Natural Convection in Bare tube
2. Vertical Shell and tube Heat exchanger (Condenser).
3. Horizontal Shell and tube Heat exchanger (Condenser)
4. Helical Coil Heat exchanger
5. Emissivity Determination
6. Effect of Geometry on Natural convection/Lagged pipe
7. Heat Transfer in Packed Beds
8. Double Pipe Heat Exchanger
9. Heat Transfer in Jacketed Vessel
10. Determination of Insulation Thickness
11. Transient Heat Conduction
12. Heat Transfer in Fluidized Beds

PART – B: OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Concept 1: Comparative study of insulation materials for a hot pipeline
2. Concept 2: Design of fin geometry for maximum heat dissipation
3. Concept 3: Performance evaluation of compact heat exchangers
4. Concept 4: Natural vs forced convection heat transfer study
5. Concept 5: Heat transfer enhancement using inserts/turbulators
6. Concept 6: Thermal analysis of waste heat recovery systems

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. J. P. Holman, "Heat Transfer", 9/e, Tata McGraw-Hill. New Delhi, 2004, ISBN-13: 9780070634510.
2. Rao Y.V.C., "Heat Transfer", ***Edition*** illustrated, reprint, University Press. 2001, ISBN 13: 9788173713842.

<u>**Reference books / Manuals:**</u>

1. McCabe and Smith "Unit Operations of Chemical Engineering".7/e, McGraw-Hill Education, ISBN-13: 978-0072848236.
2. Coulson and Richardson, "Unit Operations of Chemical Engineering" Vol.1.6/e, Butterworth-Heinamann (2006), ISBN-13: 978-8131204535.

Web links and Video Lectures (e-Resources):

1. NPTEL Heat Transfer Course/VTU Online videos
2. Virtual Heat Transfer Lab

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem Based Learning
2. Industry Expert Lecture or case studies
3. GATE Based problem solving sessions
4. Simulation demonstration using ASPEN plus
5. NPTEL Videos
6. ICT Enabled teaching

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).
The CIE Theory component will be **25 marks** and CIE Practical component will be **25 marks.**

The CIE Theory component consists of IA tests for 25 marks. The CIE Practical component for continuous assessments will be for 15 marks through rubrics and for lab tests will be for 10 marks.

- To qualify and become eligible to appear for SEE, in the **CIE theory component**, a student must score at least **40% of 25 marks**, i.e., **10 marks.**
- To qualify and become eligible to appear for SEE, in the **CIE Practical component**, a student must secure **a minimum of 40% of 25 marks**, i.e., **10 marks**.
- To pass the **SEE**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks**.
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks.**

CIE Practical component:

The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. The summation of all the experiments marks to be scaled down to 15 marks.
The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 10 marks. For laboratory test, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for CIE – Continuous assessment:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested rubrics for Practical continuous assessment:

Performance Indicators	Excellent	Very Good	Good	Satisfactory
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)

Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output (3)	Student will be able to run the program but not able to analyze the output (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching

- Role Play

Term Work (TW) and Self Learning (SL) components in Number of hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Assignment -1	6
2.	Assignment -2	6
3.	Seminar	4
4.	Industrial Visit	6
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	MOOC Courses	12
2.	Industrial case study on Heat Exchanger in a plant	8
3.	Solving GATE Level Problems	8
4.	Sustainable Heat practices in industries	4

Continuous Internal Evaluation (CIE)

(i)Theory component

The CIE marks of 25 shall be earmarked for two tests.

The first test shall be conducted after completing two modules of the syllabus and the second one after completing the rest three modules.

Each test shall be conducted for 25 marks. The average of the two tests scaled down to 25 marks shall constitute the test marks for a maximum of 25 marks.

(ii) Laboratory component

Out of 25 marks, 15 marks shall be assigned for assessment as per the rubrics listed in the course syllabus.

The remaining 10 marks shall be based on the practical test conducted by two Internal examiners appointed by the HoD. The allotment of marks shall be as per the rubrics defined for regular class work and practical test as indicated in the Table – ICs/IPCCs 1.

(i) To qualify and become eligible to appear for the SEE of the IC/IPCC, a student shall secure at least 40 % of 25 marks, i.e., 10 marks, in the CIE theory component, and at least 40 % of 25 marks, i.e., 10 marks in the CIE Practical component.

Table – ICs/IPCCs 1 Distribution of marks		
Component	**Description**	**Marks**
Allotment of marks for regular class work		
Ability in Conducting Experiments	Initiative, skill, safety practices, teamwork, and independent handling of equipment during regular lab sessions.	5 marks
Laboratory Record / Journal	Regular and neat maintenance of lab record, accuracy of results, and timely submission.	10 marks
	Subtotal	**15**
Allotment of marks for CIE practical test		

Laboratory Test / Experiment Performance	Ability to set up apparatus, follow procedure, take observations, and obtain correct results in the test experiment.	5 marks
Viva-Voce	Understanding of theory, concepts, and experimental procedure; ability to explain results and answer related questions.	5 marks
	Subtotal	**10**
	Total	**25**

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

CHEMICAL ENGINEERING THERMODYNAMICS			
Course Code	1BCH403	Scheme	2025
Type of Course	**PCC**	Semester	IV
Teaching Hours/Week (L:T:P)	28:28 : 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	28: 28 : 0 : 34	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

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

1. Develop basics of thermodynamics and apply First Law of thermodynamics to unit processes and unit operations.
2. Comprehend equations of state to determine PVT for ideal and real gases.
3. Comprehend second law of thermodynamics, Carnot principle to perform entropy calculations.
4. Enumerate different thermodynamic properties for pure fluids and solutions.
5. Apply the knowledge of phase and chemical equilibrium to chemical processes.
6. Analyse systems using concepts of equilibrium constant and standard free energy change.

Module-1

BASIC CONCEPTS:

System, surrounding and processes, Closed and open systems, Intensive and extensive properties, equilibrium state and phase rule, Zeroth law of thermodynamics, Heat reservoir and heat engines, Reversible and Irreversible processes.

FIRST LAW OF THERMODYNAMICS: General statement of First law of thermodynamics, First law for cyclic process and non-flow processes, Heat capacity.

Number of Hours: 5

Module-2

P-V-T BEHAVIOUR: P-V-T behaviour of pure fluids, Equations of state and ideal gas law, Processes involving ideal gas law: Constant volume, constant pressure, constant temperature, adiabatic and polytropic processes. Equation of state for real gases: Vander Waals equation, Redlich – Kwong equation, Peng – Robinson equation, Virial equation, Compressibility charts: Principles of corresponding states

SECOND LAW OF THERMODYNAMICS: General statements of the Second law, Concept of Entropy, The Carnot Principle, calculation of entropy changes, Clausius Inequality, Entropy and Irreversibility, Third law of Thermodynamics.

Number of Hours: 5

Module-3

THERMODYNAMIC PROPERTIES OF PURE FLUIDS: Reference Properties, Energy Properties, Derived Properties, Work function, Gibbs free energy, Relationships among thermodynamic properties, Exact differential equations, Fundamental property relations, Maxwell's equations, Clapeyron equations, Entropy heat capacity relations, Modified equations for U & H, Effect of temperature on U, H & S, Relationships between CP & CV, Gibbs- Helmholtz equation, Fugacity, Fugacity coefficient

Number of Hours: 5

Module-4

PROPERTIES OF SOLUTIONS: Partial molar properties, Chemical potential, Fugacity in solutions, Henry's law and dilute solutions, activity in solutions, Activity coefficients, Gibbs – Duhem's equation, Property changes of mixing, excess properties.

Number of Hours: 5

Module-5

PHASE EQUILIBRIA: Criteria of phase Equilibria, Criterion of stability, Duhem's theorem, Vapor – Liquid Equilibria, VLE in ideal solutions, Non-Ideal solutions, VLE at low pressures, VLE at high pressures, consistency test for VLE data, Calculation of Activity coefficients using Gibbs – Duhem's equation.

CHEMICAL REACTION EQUILIBRIUM: Reaction Stoichiometry, Criteria of chemical reaction equilibrium,

Equilibrium constant and standard free energy change, Effect of temperature, Pressure on equilibrium constants and other factors affecting equilibrium conversion, Liquid phase reactions, heterogeneous reaction equilibrium, phase rule for reacting systems.

Number of Hours: 8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Smith J.M. and Vanness H.C., "Introduction to Chemical Engineering Thermodynamics", 5/e., McGraw Hill, New York, 1996.
2. Rao Y.V.C., "Chemical Engineering Thermodynamics", New age International Publication, Nagpur, 2000.
3. Narayanan K.V., "Text book of Chemical Engineering Thermodynamics", Prentice Hall of India Private Limited, New Delhi, 2001

Reference books / Manuals:

1. Bruce E. Poling, Prausnitz, J. M., & John Paul, O. C. *The properties of gases and liquids*. New York: McGraw-Hill. 2001
2. Moran, M. J., Shapiro, H. N., Boettner, D. D., & Bailey, M. B. *Fundamentals of engineering thermodynamics*. John Wiley & Sons. 2010

Web links and Video Lectures (e-Resources):

1. MOOC courses on Thermodynamics
2. Learn ChemE Simulations

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. GATE-oriented problem-solving sessions.
2. Industry expert lectures on process thermodynamics applications.
3. Case-Based Teaching involving power plants, refrigeration and separation processes.
4. Simulation-based learning using Aspen HYSYS and DWSIM.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Industrial Thermodynamic Case Study	10
2.	MOOC/NPTEL Completion Activity	15
3.	Thermodynamic problem solved with interpretation of results and its report presentation.	15

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Phase Equilibrium Numerical Case Study	10
2.	Seminar on Modern Thermodynamic Applications	20
3.	Assignment on Thermodynamic Calculations	10
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	NPTEL/SWAYAM Module on Chemical Engineering Thermodynamics	20
2.	Literature Review on Emerging Applications of Thermodynamics in Energy Systems	10
3.	GATE-Level Problem Solving Practice	10

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

INDUSTRIAL POLLUTION CONTROL AND MANAGEMENT			
Course Code	1BCH404	Scheme	2025
Type of Course	**PCC**	Semester	IV
Teaching Hours/Week (L:T:P)	42: 0: 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 0 : 0 : 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

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

1. Outline the importance of the environment and its impact, standards and legislation of environment.
2. Interpret various waste water parameter and develop and design the different methods of waste water treatment techniques.
3. Develop and design the different waste water treatment techniques for Industries.
4. Identify the sources of different types of air pollutants, their prevention and design of control techniques in industries.
5. Illustrate the different methods for reducing solid waste and noise pollution in industries.

Module-1

Introduction: Importance of Environment for Mankind. Types of pollution, Damages from environmental pollution, impact of climate change, Need of environmental standards legislation and acts, functions of central and state boards, EIA, EIS and EMP, water and air indices, Recent trends in waste minimization and management, LCA, zero discharge concept.

Number of Hours: 8

Module-2

Sampling and Analysis of Waste Water and Treatment: Water resources. Wastewater classification. Types of water pollutants. Waste water sampling, Methods of Analysis: DO, BOD, COD, TOC, Nitrogen, Phosphorus, Trace Elements and Alkalinity. Waste water treatment: preliminary, primary, secondary. Design of sedimentation tanks and biological treatment processes (Activated sludge process and Trickling filters).

Number of Hours:10

Module-3

Advance Waste Water and Sludge Treatment: Significance of Tertiary or Advanced wastewater Treatment, Adsorption on Activated Carbon, Ion Exchange, Reverse Osmosis, Electro dialysis cell. Advanced bioreactors. Sludge treatment and disposal. Industrial Case studies.

Number of Hours:8

Module-4

Air Pollution and Treatment: Definition, Sources, Classification, Properties of air pollutants, Effects of air pollution on health vegetation and materials. Air pollution sampling and analysis. Air pollution meteorology. Control methods and equipment's for particulates and gaseous pollutants. Selection design and performance analysis of air pollution control equipment: gravity settling chambers, cyclone separator, ESPs, filters and wet scrubbers. Adsorption, absorption and condensation. Industrial case studies.

Number of Hours:8

Module-5

Solid Waste Treatment and Noise Pollution: Sources and Classification, Effect on public health, properties, soil microbiology, 5R's of Solid Waste, Integrated Solid waste management, Disposal Methods-compositing, sanitary landfill, briquetting/gasification and incineration. Hazardous and biomedical waste. Noise pollution: Definition, Sources, Effects of Noise, Noise sampling and Measurement, Approaches for Noise Control.

Number of Hours:8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. C. S. Rao "Environmental Pollution Control Engineering" 2/e, New Age International 2006. ISBN: 81-224-1835-X
2. S.P. Mahajan, "Pollution Control in Process Industries", Tata McGraw Hill. 1985.
3. Peirce, J. J., Vesilind, P. A., & Weiner, R. 4/e, *Environmental pollution and control*. Butterworth-Heinemann. 1998.

Reference books / Manuals:

4. Metcalf and Eddy, "Waste Water Engineering Treatment Disposal Reuse" Tata McGraw Hill, 4/e, 2003.
5. Frank Kreith and George Tchobanoglous "Hand book of Solid waste Management", 2/e, Tata Mc-Graw Hill, 2002

Web links and Video Lectures (e-Resources):

1. **MOOC Environmental Courses**
2. **Central Pollution Control Board/State Pollution Control Board**
3. **US EPA Environmental Education Resources**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. ICT-enabled demonstrations and environmental simulation tools.
2. Field visits to STP/ETP/CETP facilities.
3. Case-Based Teaching using industrial pollution incidents.
4. SDG-oriented environmental management projects.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks.**
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	SDG Related activities or Mini projects	10
2.	Group discussion based on Zero discharge industries, Air and Water Quality Index etc.	15
3.	Case studies on Pollution Prevention studies	15
4.	NPTEl/MOOC Courses related to Pollution management.	10

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Assignment on Environmental Legislation and Standards, EIA, EMP.	10
2.	Seminar on Emerging Pollution Control Technologies	10
3.	Environmental Audit / EIA Report Preparation	10

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	NPTEL/SWAYAM Course Module on Environmental Engineering	20
2.	Literature Review on Zero Liquid Discharge, Carbon Neutrality and Circular Economy	10
3.	Video-based Learning on Industrial ETP/STP/Air Pollution/Water pollution/Solid waste management	20

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade ‘F’ (Fail).

Chemical Reaction Engineering-I			
Course Code	1BCH405	Scheme	2025
Type of Course	**PCC**	Semester	IV
Teaching Hours/Week (L:T:P)	42: 0 : 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	42: 0 : 0 : 48	SEE Marks	50
Credits	**3**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	3

Course outcome (Course Skill Set)

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

1. Determine rate, rate constant, activation energy and order of reaction.
2. Analyse and interpret batch reactor data.
3. Design batch reactor, ideal PFR and MFR.
4. Analyse the performance of reactors with multiple reactions.
5. Interpret the effect of temperature on reactor performance.

Module-1

Kinetics of Homogeneous Reactions: classification of reactions, Rate equation and rate of reaction. Molecularity and order of reaction Factors affecting the rate of reaction. Chemical kinetics and equilibrium constant. Arrhenius and collision theories. Elementary and non-elementary reactions.

Number of Hours:10

Module-2

Interpretation of Batch Reactor Data: Constant volume batch reactor. Analysis of total pressure data, Integral and differential methods of analysis for constant and half life and method of excess. Reversible first and second order reactions.

Number of Hours:8

Module-3

Ideal Reactors for Single Reaction: Ideal batch reactor, steady-state mixed and plug-flow reactors, space time and space velocity for flow reactors, variable volume reactions.

Number of Hours:8

Module-4

Multiple Reactions and Reactors: Series and parallel reactions, yield and selectivity, multiple reactors: plug and mixed flow reactors.

Number of Hours:8

Module-5

Heat effects, Recycle Reactor with Purging: Heat of reactions, effect of temperature on heat of reaction, reactor design, effect of recycle ratio and purge ratio on conversion.

Number of Hours:8

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Octave Levenspiel, "Chemical Reaction Engineering", 3/e, John Wiley & Sons, 2004, ISBN:978-81-265-1000-9
2. J. M. Smith, "Chemical Engineering Kinetics", 3/e, McGraw Hill, 1981.ISBN:0-07 066574-5

Reference books / Manuals:

1 Luyben, W. L. (2007). *Chemical reactor design and control*. John Wiley & Sons.

2Mann, U. (2009). *Principles of chemical reactor analysis and design: new tools for industrial chemical reactor operations*. John Wiley & Sons.

3. H. Scott Fogler, "Elements of Chemical Reaction Engineering", 3/e, Prentice Hall 2006. ISBN: 978-81-203-3416-8

Web links and Video Lectures (e-Resources):

1. NPTEL Chemical Reaction Engineering Courses
2. CHEMICAL GATE Websites

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem-Based Learning involving reactor design and kinetics.
2. Case-Based Teaching using industrial reactor performance data.
3. ICT-enabled visualization of reactor models and kinetic behavior.
4. Simulation exercises using MATLAB, POLYMATH, Excel and DWSIM.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests(IA)** shall be conducted, carrying a total of **25 marks**.

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks**.

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Mini Project / Case Study on Industrial Chemical Reactors	15
2.	Kinetic Data Analysis and Reactor Design Assignment	10

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester		
Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)		
Sl. No.	**Term Work (TW) Activity**	**Number of Hours / Semester**
1.	Reactor Design Numerical Problems (Batch, PFR, CSTR)	10
2.	Seminar on Industrial Reactor Applications	10
3.	Assignment on Reaction Kinetics and Rate Laws	10
SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.		
Sl. No.	**Self-Learning (SL) Activity**	**Number of Hours / Semester**
1.	NPTEL/SWAYAM Module on Chemical Reaction Engineering	20
2.	Literature Review on Emerging Reactor Technologies and Process Intensification	15
3.	GATE-Level Problem Solving	15

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.

(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.

(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.

(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.

For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).

Instrument analysis and Pollution Control Lab		Scheme	2025
Course Code	1BCHL406	Semester	IV
Teaching Hours/Week (L:T:P)	0: 0 : 28	CIE Marks	50
Total Hours of Pedagogy L:T:P:SLTW	0: 0: 28 :2	SEE Marks	50
Credits	1	Total Marks	100
Examination type (SEE)	**Practical**	Exam Hours	3

Course outcome (Course Skill Set)

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

1. Experimentally verify the principles and working of instruments studied in theory.
2. Know the use of skills in handling various analytical instruments.
3. Use various analytical instruments for analysis of various parameters.
4. Evaluate the to compare with reported literature.
5. Apply theoretical knowledge of various Analytical Instruments.
6. Acquire practical knowledge to handle analytical instruments for determining pollution parameters to control pollutants

Note:

1. The laboratory syllabus consists of PART-A and PART-B. While PART-A has 6 conventional experiments, PART-B has 6 typical open-ended experiments. The maximum marks for the laboratory course are 100.
2. Both PART-A and PART-B are considered for CIE and SEE.
3. Students have answer 1(one) question from PART-A and 1(one) question from PART-B.
   a. The questions set for SEE shall be from among the experiments under PART-A. It is evaluated for **70 marks** out of the maximum 100 marks.
   b. The open-ended question set for SEE shall be any other open-ended question and not selected from the experiments under PART-A. It shall be evaluated for **30 marks.**
4. For Continuous Internal Evaluation (CIE) during the semester, classwork shall typically include open-ended questions from **Part-B**, along with other similar questions designed to enhance the students' skills.

PART – A
FIXED SET OF EXPERIMENTS

1. Analysis of effluents for pH, alkalinity and turbidity….
2. Determination of COD and BOD.
3. Volatile, Fixed, Filterable and Dissolved solid analysis.
4. UV Spectrophotometer
5. Flame photometer
6. Turbidimeter
7. Potentiometer titration
8. Viscometer
9. Dissolved oxygen
10. Bomb calorimeter
11. Measurement of particulate matter in Air
12. Measurement of SO2 in air
13. KF Auto titrator
14. Orsat Apparatus

PART – B

OPEN ENDED EXPERIMENTS

Open-ended experiments are a type of laboratory activity where the outcome is not predetermined and students are given the freedom to explore, design, and conduct the experiment based on the problem statements as per the concepts defined by the course coordinator. It encourages creativity, critical thinking, and inquiry-based learning.

1. Concept 1: Comparative analysis of drinking water samples collected from different sources using pH, turbidity, alkalinity, TDS and conductivity measurements.
2. Concept 2: Design and conduct an experiment to assess the efficiency of a low-cost adsorbent for COD reduction from synthetic wastewater.
3. Concept 3: Determination and comparison of moisture content in different industrial solvents using Karl Fischer Titrator.
4. Concept 4: Air quality assessment of different campus locations by measuring particulate matter and gaseous pollutants.
5. Concept 5: Investigation of factors affecting UV absorbance of colored solutions and development of calibration curves for unknown sample estimation.
6. Concept 6: Design and evaluate a simple wastewater treatment methodology and compare pre-treatment and post-treatment water quality parameters.

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. C. S. Rao "Environmental Pollution Control Engineering" 2/e, New Age International 2006. ISBN: 81-224-1835-X
2. Willard, H. H., & Dean, S. Instrumental methods of analysis, CBS Publishers and Distributors. *New Delhi*, *580*, 626. 1986.

<u>Reference books / Manuals:</u>

1. Verma, S., Kanwar, V. S., & John, S. *Environmental engineering: fundamentals and applications*. CRC Press. 2022.

2. Laboratory Manuals supplied with the Instruments.

Web links and Video Lectures (e-Resources):

1. Virtual labs

2. CPCB/APHA Guidelines

3. NPTEL Instrumentation and Pollution Control courses

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Demonstration-based Learning using sophisticated analytical instruments.
2. Virtual Laboratory Simulations before actual experimentation.
3. Industry Exposure through Environmental Testing Laboratory Visits.

Assessment Structure:
The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.
For both CIE and SEE, the student is required to conduct one experiment each from both Part A and Part B.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks.**

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Chemical Process for Automobile Development			
Course Code	**1BCHL407A**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	IV
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

- Understand the basic principles of chemical processes used in automobile manufacturing and development.
- Explain the role of chemistry in automotive fuels, lubricants, coolants, batteries, paints, coatings, and other materials.
- **Analyse** the properties and performance of fuels and alternative energy sources used in automobiles.
- Apply chemical-process concepts to the selection and treatment of automotive materials and components.
- Evaluate corrosion, wear, oxidation, and degradation processes affecting automobile components.

SET OF EXPERIMENTS

1. Epoxy curing study
2. Composite fabrication by hand lay-up
3. Rubber vulcanization
4. Electrochemical cell construction
5. Charge-discharge analysis of battery
6. Supercapacitor fabrication
7. Zinc phosphating of steel
8. Corrosion rate measurement
9. Electrodeposition coating
10. Lubricant viscosity measurement
11. Plastic recycling by solvent method
12. Simplified LCA of automotive materials

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Geoffrey Davies, "Materials for Automobile Bodies" 3rd Edition, Butterworth-Heinemann,2003.
2. Richard Stone and Jeffrey K. Ball, "Automotive Engineering Fundamentals" , SAE International in 2004.

Reference books / Manuals:

1. John Newman and Karen E. Thomas-Alyea, "*Electrochemical Systems", 3rd edition, 2004, Wiley.*

Web links and Video Lectures (e-Resources):
Teaching-Learning Process (Innovative Delivery Methods): The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes. 1. 2.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a**

minimum of 40% of 50 marks, i.e., **20 marks.**

- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**
- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks.**

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Synthesis of Green Energy in lab scale and study			
Course Code	1BCHL407B	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	IV
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

1. Explain the working principles and synthesis methods of green energy sources such as biofuels, hydrogen, biogas, and solar-based materials.
2. Perform laboratory-scale synthesis and preparation of selected green energy materials or fuels using appropriate techniques.
3. Analyze the physical, chemical, and energy-related properties of synthesized green energy products.
4. Evaluate the efficiency, performance, and environmental benefits of different green energy technologies.

SET OF EXPERIMENTS

1. Calorific value determination of biomass fuel
2. Proximate analysis of biomass
3. Laboratory energy audit
4. Biodiesel production by transesterification
5. Biodiesel property evaluation (density and viscosity)
6. Bioethanol production by fermentation
7. Biogas generation demonstration
8. Hydrogen generation by water electrolysis
9. PEM fuel cell characterization
10. Solar cell efficiency measurement
11. Battery charge-discharge analysis
12. FTIR characterization of biodiesel

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. G. D. Rai, “Non-Conventional Energy Sources”, Khanna Publishers, New Delhi.
2. D. Mukherjee and S. Chakrabarti, “Fundamentals of Renewable Energy Systems”, New Age International (P) Ltd, 2004.

Reference books / Manuals:

1. Caye M. Drapcho, Nhuan P. T. Nhuan and Terry H. Walker, “Biofuels Engineering Process Technology”, McGraw-Hill Professional, 2008.

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
1.
2.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**

- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

Computational Fluid Dynamics			
Course Code	**1BCHL407C**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	IV
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

1. Formulate the continuity, momentum, and energy equations
2. Classify physical flow behaviours into various geometry
3. Understand methods to convert continuous differential equations into discrete algebraic equations using Finite Difference (FDM) and Finite Volume (FVM) approaches.
4. Analyse consistency, convergence, and numerical errors in computational schemes.
5. Generate structured or unstructured computational grids/meshes.
6. Operate industry-standard simulation software packages to model external fluid flows.

SET OF EXPERIMENTS

1. Pipe flow simulation
2. Laminar vs turbulent flow
3. Sudden expansion/contraction
4. Flow around cylinder
5. Stirred tank mixing
6. Heated pipe flow
7. Composite wall conduction
8. Heat exchanger simulation
9. PFR flow analysis
10. Species transport with reaction in PFR
11. Packed bed pressure-drop analysis
12. Mini project

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. H. K. Versteeg and W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method", 2nd edition, pearson.

Reference books / Manuals:

1. 1. Ferziger,Joel H.,Milovan Perić, and Robert L. Street. Computational methods for fluid dynamics. Berlin: Springer, 2002

Web links and Video Lectures (e-Resources):

Teaching-Learning Process (Innovative Delivery Methods):
The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.
1.
2.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**

- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
Implementation (8) (PO3 & PO8)	Student is capable of implementing the design with best suitable algorithm considering optimal solution. (7-8)	Student is capable of implementing the design with best suitable algorithm and should be capable of explaining it (5-6)	Student is capable of implementing the design with proper explanation. (3-4)	Student is capable of implementing the design. (1-2)
Result &Analysis (5) (PO4)	Student is able to run the program on various cases and compare the result with proper analysis. (5)	Student will be able to run the program for all the cases. (4)	Student will be able to run the code for few cases and analyze the output. (3)	Student will be able to run the program but not able to analyze the output. (1-2)
Demonstration (8) (PO9)	The lab record is well-organized, with clear sections (e.g., Introduction, Method, Results, Conclusion). Transitions between sections are smooth. (7-8)	The lab record is organized, with clear sections, but some sections are not well-defined. (5-6)	The lab record lacks clear organization or structure. Some sections are unclear or incomplete. (3-4)	The lab record is poorly organized, with missing or unclear sections. (1-2)

Note: Can add Engineering & IT tool usage based on the nature of the course

ANSYS for Chemical Engineers			
Course Code	**1BCHL407C**	Scheme	2025
Type of Course	Ability Enhancement Course (Laboratory)	Semester	IV
Teaching Hours/Week (L :T : P)	0: 0 : 1	CIE Marks	50
Total Hours of Pedagogy L :T:P:SL:TW	0: 0 :28 :2	SEE Marks	50
Credits	01	Total Marks	100
Type of Examination	Practical	Exam Hours	03

Course outcome (Course Skill Set)

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

1. Create accurate 2D and 3D geometries of chemical process equipment and generate high-quality, grid-independent meshes.
2. Analyze complex fluid behavior in process piping, valves, and fittings using appropriate laminar and turbulence models
3. Interpret simulation data through visual contours, and streamline animations to write comprehensive technical engineering reports.

SET OF EXPERIMENTS

1. Introduction to ANSYS Fluent
2. Laminar Flow Through Pipe
3. Flow Through Sudden Expansion
4. Venturi Meter Analysis
5. Flow Around Cylinder
6. Mixing in Stirred Tank
7. Heated Pipe Flow
8. Composite Wall Heat Transfer
9. Packed Bed Pressure Drop
10. Species Transport in Tubular Reactor
11. Simulation to determination pressure drop for laminar flow through a circular pipe
12. Flow Through Sudden Expansion and Contraction

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Versteeg, Henk Kaarle, and Weeratunge Malalasekera. An introduction to computational fluid dynamics: the finite volume method. Pearson Education, 2007.

Reference books / Manuals:

1. https://ae.iitm.ac.in/~krishna/ecfd4tab.pdf

Web links and Video Lectures (e-Resources):

1. https://nptel.ac.in/courses/112105045 NPTEL Video Computational Fluid Dynamics, IIT Kharagpur

Prof. S. Chakraborty

2. https://nptel.ac.in/courses/103105679 Prof. Arnab Datta, IIT, Kharagpur

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Introduction to the use of modern CFD software, including geometry building, mesh generation, solution techniques, and flow visualization.
2. The investigation of various fluid flow systems aimed at a deeper understanding of the basic principles of fluid mechanics.
3. Experience with some of the difficulties that one may encounter in CFD, such as geometry simplification, mesh problems, convergence problems, multiple solutions, etc.

Assessment Structure:

The assessment for each course is equally divided between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each component carrying **50% weightage** (i.e., 50 marks each).

The CIE marks awarded shall be based on the continuous evaluation of the laboratory report using a defined set of rubrics. Each experiment report can be evaluated for 30 marks. Total marks for the all report shall be scaled down to 30 marks. The laboratory test (duration 03 hours) at the end of the last week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and Marks scored shall be scaled down to 20 marks. Final average of marks for report and test shall be out of 50 marks.

Rubrics for CIE – Continuous assessment:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Rubrics for SEE / CIE Test:

	Superior	**Good**	**Fair**	**Needs Improvement**	**Unacceptable**
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

- To qualify and become eligible to appear for SEE, in the **CIE component**, a student must secure **a minimum of 40% of 50 marks**, i.e., **20 marks.**
- To pass the **SEE component**, a student must secure **a minimum of 35% of 50 marks**, i.e., **18 marks.**

- A student is deemed to have **successfully completed the course** if the **combined total of CIE and SEE is at least 40 out of 100 marks**.

Rubrics suggested for Practical continuous assessment				
Performance Indicators	**Excellent**	**Very Good**	**Good**	**Satisfactory**
Fundamental Knowledge (4) (PO1)	The student has well depth knowledge of the topics related to the course (4)	Student has good knowledge of some of the topics related to course (3)	Student is capable of narrating the answer but not capable to show in depth knowledge (2)	Student has not understood the concepts clearly (1)
Design Of Experiment (5) (PO2 & PO3)	Student is capable of discussing more than one design for his/her problem statement and capable of proving the best suitable design with proper reason (5)	Student is capable of discussing few designs for his/her problem statement but not capable of selecting best (4)	Student is capable of discussing single design with its merits and de-merits (3)	Student is capable of explaining the design (1-2)
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Note: Can add Engineering & IT tool usage based on the nature of the course

BIOLOGY FOR CHEMICAL ENGINEERS			
Course Code	1BRM408	Scheme	2025
Type of Course	**PCC**	Semester	IV
Teaching Hours/Week (L:T:P)	28: 0 : 0	CIE Marks	50
Total Hours of Pedagogy per semester L /T/P/SL&TW:	28: 0 : 0 : 32	SEE Marks	50
Credits	**2**	Total Marks	100
Examination type (SEE)	Theory	Exam Hours	2

Course outcome (Course Skill Set)

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

1. Elucidate the basic biological concepts via relevant industrial applications and case studies.
2. Evaluate the principles of design and development, for exploring novel bioengineering projects.
3. Corroborate the concepts of biomimetics for specific requirements.
4. Develop critical thinking towards exploring innovative biobased solutions for socially relevant problems.

Module-1

BIOMOLECULES AND THEIR APPLICATIONS (QUALITATIVE): Carbohydrates (cellulose-based water filters, PHA and PLA as bioplastics), Nucleic acids (DNA Vaccine for Rabies and RNA vaccines for Covid19, Forensics – DNA fingerprinting), Proteins (Proteins as food – whey protein and meat analogs, Plant based proteins), lipids (biodiesel, cleaning agents/detergents), Enzymes (glucose-oxidase in biosensors, lignolytic enzyme in bio-bleaching).

Number of Hours: :5

Module-2

HUMAN ORGAN SYSTEMS AND BIO DESIGNS - 1 (QUALITATIVE): Brain as a CPU system (architecture, CNS and Peripheral Nervous System, signal transmission, EEG, Robotic arms for prosthetics. Engineering solutions for Parkinson's disease).Eye as a Camera system (architecture of rod and cone cells, optical corrections, cataract, lens materials, bionic eye).Heart as a pump system (architecture, electrical signalling - ECG monitoring and heart related issues, reasons for blockages of blood vessels, design of stents, pace makers, defibrillators).

Number of Hours:5

Module-3

HUMAN ORGAN SYSTEMS AND BIO-DESIGNS - 2 (QUALITATIVE): Lungs as purification system (architecture, gas exchange mechanisms, spirometry, abnormal lung physiology - COPD, Ventilators, Heart-lung machine).Kidney as a filtration system (architecture, mechanism of filtration, CKD, dialysis systems). Muscular and Skeletal Systems as scaffolds (architecture, mechanisms, bioengineering solutions for muscular dystrophy and osteoporosis).

Number of Hours:8

Module-4

NATURE-BIOINSPIRED MATERIALS AND MECHANISMS (QUALITATIVE): Echolocation (ultrasonography, sonars), Photosynthesis (photovoltaic cells, bionic leaf). Bird flying (GPS and aircrafts), Lotus leaf effect (Super hydrophobic and self-cleaning surfaces), Plant burrs (Velcro), Shark skin (Friction reducing swim suits), Kingfisher beak (Bullet train). Human Blood substitutes - haemoglobin-based oxygen carriers (HBOCs) and perflouro carbons (PFCs).

Number of Hours:5

Module-5

TRENDS IN BIOENGINEERING (QUALITATIVE): Bioprinting techniques and materials, 3D printing of ear, bone and skin. 3D printed foods. Electrical tongue and electrical nose in food science, DNA origami and Biocomputing, Bioimaging and Artificial Intelligence for disease diagnosis. Self-healing Bio concrete (based on bacillus spores, calcium lactate nutrients and biomineralization processes) and Bioremediation and Biomining via microbial surface adsorption (removal of heavy metals like Lead, Cadmium, Mercury, Arsenic).

Number of Hours: 5

Suggested Learning Resources: (Text Book/ Reference Book/ Manuals):

Text books:

1. Biology for Engineers, Thyagarajan S., Selvamurugan N., Rajesh M.P., Nazeer R.A., Thilagaraj W., Barathi S., and Jaganthan M.K., Tata McGraw-Hill, New Delhi, 2012.
2. Biology for Engineers, Arthur T. Johnson, CRC Press, Taylor and Francis, 2011
3. Biology for Engineers, Sohini Singh and Tanu Allen, Vayu Education of India, New Delhi, 2014.
4. Biomimetics: Nature-Based Innovation, Yoseph Bar-Cohen, 1st edition, 2012, CRC Press.
5. Bio-Inspired Artificial Intelligence: Theories, Methods and Technologies, D. Floreano and C. Mattiussi, MIT Press, 2008.

Reference books / Manuals:

1. Human Physiology, Stuart Fox, Krista Rompolski, McGraw-Hill eBook. 16th Edition, 2022
2. Biomedical Instrumentation, Leslie Cromwell, Prentice Hall 2011.
3. Bioremediation of heavy metals: bacterial participation, by C R Sunilkumar, N Geetha A C Udayashankar Lambert Academic Publishing, 2019.
4. 3D Bioprinting: Fundamentals, Principles and Applications by Ibrahim Ozbolat, Academic Press, 2016.
5. Electronic Noses and Tongues in Food Science, Maria Rodriguez Mende, Academic Press, 2016.

Web links and Video Lectures (e-Resources):

1. **MOOC Biology Courses**
2. **National Center for Biotechnology Information**
3. **Khan Academy Biology**

Teaching-Learning Process (Innovative Delivery Methods):

The following are sample strategies that educators may adopt to enhance the effectiveness of the teaching-learning process and facilitate the achievement of course outcomes.

1. Problem-Based Learning on societal and healthcare challenges.
2. ICT-enabled animations and biological simulations.
3. Design Thinking Activities for biomimetic product development.
4. Case-Based Teaching using biomedical and bioengineering innovations.

Assessment Structure:

The assessment in each course is divided equally between Continuous Internal Evaluation (CIE) and the Semester End Examination (SEE), with each carrying 50% weightage.

- To qualify and become eligible to appear for SEE, in the **CIE**, a student must score at least **40% of 50 marks**, i.e., **20 marks**.
- To pass the **SEE**, a student must score at least **35% of 50 marks**, i.e., **18 marks**.
- Notwithstanding the above, a student is considered to have **passed the course,** provided the combined total of **CIE and SEE** is at least **40 out of 100 marks**.

Continuous Comprehensive Assessments (CCA)+ Internal Assessment Test (IA) = Continuous Internal Evaluation CIE [25+25=50 marks]

A minimum of **two Internal Assessment Tests (IA)** shall be conducted, carrying a total of **25 marks.**

In addition, **Continuous Comprehensive Assessment (CCA)** shall be conducted for a total of **25 marks.**

It is recommended to include **a maximum of two learning activities** as part of the CCA to foster the **holistic development of students.** These activities shall be:

Sl. No.	Name of the Learning activity	Maximum Marks
1.	Case Study Presentation	15
2.	Literature Review on Emerging Bioengineering Technologies	15
3.	Group Discussion on Biobased Sustainable Technologies	10
4.	Scientific Poster Preparation	10

Rubrics for Learning Activity (Based on the nature of learning activity, design the rubrics for each activity):

	Superior	Good	Fair	Needs Improvement	Unacceptable
Performance Indicator- 1 (CO/PO Mapping)					
Performance Indicator-2 (CO/PO Mapping)					
...					
Performance Indicator-n (CO/PO Mapping)					

Suggested Learning Activities may include (but are not limited to):

- Course Project
- Case Study Presentation
- Programming Assignment
- Tool/Software Exploration
- Literature Review
- Open Book Test (preferably at RBL4 and RBL5 levels)
- GATE-based Aptitude Test
- Assignment (at RBL3, RBL4, or RBL5 levels)
- Any other relevant and innovative academic activity
- Use of MOOCs and Online Platforms

Suggested Innovative Delivery Methods may include (but are not limited to):

- Flipped Classroom
- Problem-Based Learning (PBL)
- Case-Based Teaching
- Simulation and Virtual Labs
- Partial Delivery of course by Industry expert/ industrial visits
- ICT-Enabled Teaching
- Role Play

Term Work (TW) and Self Learning (SL) components in Number of Hours per semester

Term work (includes assignments, seminars, micro projects, industrial visits, any other student activities etc.)

Sl. No.	Term Work (TW) Activity	Number of Hours / Semester
1.	Literature Review on Bioinspired Materials	20
2.	Biomimicry Case Study Presentation	20
3.	Seminar on Emerging Bioengineering Trends	20

SL: Self Learning, MOOCs, spoken tutorials, online educational resources etc.

Sl. No.	Self-Learning (SL) Activity	Number of Hours / Semester
1.	Study of Recent Advances in Bioprinting and AI in Healthcare	20
2.	SWAYAM Module on Biology for Engineers	20
3.	Mini Project / Poster Presentation	20

Continuous Internal Evaluation (CIE)

(i)The CIE marks shall be decided based on internal tests and other outcome-based activities. The continuous internal evaluation shall be carried out by the teacher handling the course.
(ii)Out of 50 marks earmarked for CIE, 25 marks shall be assigned for internal tests. The first test shall be conducted after completing two modules of the syllabus and the second one after completing the remaining three modules.
(iii) The remaining 25 marks shall be assigned for Continuous Course Assessment (CCA), conducted as per the rubrics listed in the assessment section of the respective syllabus.
(iv) A student shall obtain a minimum of 40% marks or 20 out of 50 marks allotted to CIE to become eligible to appear for the SEE.

Passing requirement in SEE

For a pass in the Semester End Examination (SEE), a student shall secure a minimum of 35 marks out of 100.
For the declaration of a pass grade, the sum of the Continuous Internal Evaluation (CIE) marks (out of 50) marks and the SEE marks scaled down to 50 shall be greater than or equal to 40 marks. If the total (CIE + SEE) is less than 40 marks, the student shall be awarded the grade 'F' (Fail).