| FINITE ELEMENT METHODS | | Semester | 7 |
|---|---|---|---|
| Course Code | **BME701** | CIE Marks | 50 |
| Teaching Hours/Week (L:T:P: S) | 3:0:2:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 hours Theory + 8-10 Lab slots | Total Marks | 100 |
| Credits | 04 | Exam Hours | 3 |
| Examination nature (SEE) | Theory | | |

**Course objectives:**

1. To learn basic principles of finite element analysis procedure.
2. To learn the theory and characteristics of finite elements that represent engineering structures.
3. To learn and apply finite element solutions to structural, thermal, dynamic problem to develop the knowledge and skills needed to effectively evaluate finite element analyses.

**Teaching-Learning Process (General Instructions)**

These are sample Strategies; that teachers can use to accelerate the attainment of the various course outcomes.

There are two components to the course: the theoretical part will expose the key concepts (weighted-residual method, natural vs. essential boundary conditions, basis functions, error measures, etc) and the technical details (element types, integration rules, equation assembly, post-processing, etc). The second component aims at providing hands-on experience with the method through its application to simple problems (bars, trusses & beams, dynamic and heat transfer, etc) of engineering interest and to problems that merit the use of a computational tool. Subject to the pace of the class, practical component is considered using software. The presentation of the material will be incremental starting from simple one-dimensional problems in order to illustrate and solidify the concepts and will progress to two- and three. The emphasis will be on the basic principles, in the methodology and in the physical interpretation of numerical results.

**MODULE-1**

**Introduction to FEM:**

Introduction to FEM, engineering applications, advantages, General steps, Element types, Convergence criteria, Coordinate systems, commercial packages-pre-processor, solver and post processor.

Principles of Elasticity: Strain- displacement relations, Stress-strain relations for 1D, 2D, and 3D cases, Plain stress and Plain strain conditions,

Introduction to Numerical Methods, Potential energy method, Rayleigh-Ritz method and Galerkin method-applied to simple problems on axially loaded members, cantilever, simply supported beams, with point loads and distributed loads.

**MODULE-2**

**One Dimensional Element:**

Formulation of a linear bar element, Shape Functions- Polynomial, The Potential Energy Approach, derivation of stiffness matrix, Properties of stiffness matrix, Assembly of Global Stiffness Matrix and Load Vector, Boundary conditions- elimination method and penalty method. Numerical Problems on straight and stepped bars. **(Problems with 2 elements only).**

**MODULE-3**

**Trusses and Beams:**

Formulation plane trusses element, Stiffness matrix (No derivation), Numerical Problems on point load, Formulation beam element, derivation of Hermite shape functions, stiffness matrix and load vector (No derivations), Numerical Problems on beams carrying concentrated, UDL and couples. **(Problems with 2 elements only).**

**MODULE-4**

**Two dimensional Element:**
Formulation of triangular and quadrilateral elements. Displacement models and shape functions for linear and higher order elements, Lagrangian and serendipity elements, Iso parametric – sub parametric – super parametric elements, Introduction to axisymmetric– triangular elements. Convergence criteria, pascal triangle. (No numerical problems)

**MODULE-5**

**Dynamic considerations and Heat Transfer:**
Dynamic considerations: Formulation for point mass and distributed masses, Consistent mass matrices for 1-D bar element, computation of eigen values and eigen vectors. Numerical Problems on straight and stepped bars.
**Heat Transfer Problems**: Steady state heat transfer, 1D heat conduction governing equation, boundary conditions, Numerical problems on composite wall, 1D heat transfer in thin fins.

**PRACTICAL COMPONENT OF IPCC** *(May cover all / major modules)*

| Sl.NO | Experiments |
|---|---|
| 1 | Bars of constant cross section area, tapered cross section area and stepped bar with different materials |
| 2 | Trusses – (Minimum 3 exercises of different areas of cross sections of links, different supports such as fixed support, rolling support) |
| 3 | Beams – Simply supported, cantilever, beams with point load, UDL, beams with varying load etc. (Minimum 6 exercises) |
| 4 | Stress analysis of a rectangular plate with a circular hole |
| 5 | Thermal Analysis – 1D & 2D problem with conduction and convection boundary conditions (Heat transfer through composite section) Minimum of 2 exercises |
| 6 | Natural frequency of beam with fixed – fixed end condition |
| 7 | Response of beam with fixed – fixed end conditions subjected to forcing function |
| 8 | Demonstrate the use of graphics standards (IGES, STEP etc) to import the model from modeler to solver |
| 9 | **Can be Demo experiments for CIE** Demonstrate the use of graphics standards ( IGES, STEP etc ) to import the model from modeler to solver |
| 10 | **Can be Demo experiments for CIE** Demonstrate one example of contact analysis to learn the procedure to carry out contact analysis. |
| 11 | **Can be Demo experiments for CIE** Demonstrate at least two different type of example to model and analyze bars or plates made from composite material |

**Course outcomes (Course Skill Set):**
At the end of the course, the student will be able to:

1. Understand the concepts behind formulation methods in FEM.
2. Identify the application and characteristics of FEM elements such as bars, beams, plane and iso-parametric elements.
3. Develop element characteristic equation and generation of global equation.
4. Apply suitable boundary conditions to a global equation for bars, trusses, beams, circular shafts, heat transfer, fluid flow, axi symmetric and dynamic problems.
5. Solving of displacements, stress and strains induced problems.

**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 out of 50) and for the

SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**CIE for the theory component of the IPCC (maximum marks 50)**

- IPCC means practical portion integrated with the theory of the course.
- CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.
- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.
- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

**CIE for the practical component of the IPCC**

- **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks** for the test to be conducted after the completion of all the laboratory sessions.
- On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.
- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be conducted for 50 marks and scaled down to **10 marks.**
- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

**SEE for IPCC**

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks

**The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component**.

**Suggested Learning Resources:**

**Text Books:**


1. Logan, D. L., A first course in the finite element method,6th Edition, Cengage Learning, 2016.
2. Rao, S. S., Finite element method in engineering, 5th Edition, Pergaman Int. Library of Science, 2010.
3. Chandrupatla T. R., Finite Elements in engineering, 2nd Edition, PHI, 2013.
4. O. C. Zienkiewicz and Y.K. Cheung, The Finite Element Method in Structural and Soild Mechanics, McGraw Hill, London

**Reference Books:**


1. J.N.Reddy, "Finite Element Method"- McGraw -Hill International Edition.Bathe K. J. Finite Elements Procedures, PHI.
2. Cook R. D., et al. "Conceptsand Application of Finite Elements Analysis"- 4th Edition, Wiley & Sons, 2003.
3. C.S.Krishnamoorty, Finite ElementAnalysis, Tata McGraw-Hill David V. Hutton, Fundamentals of Finite ElementAnalysis, McGraw Hill
4. D. Maity, Computer Analysis of Framed Structures, I.K. International Pvt. Ltd. New Delhi
5. Erik G. Thompson, Introduction to the Finite Element Method: Theory, Programming and Applications, John Wiley


**Web links and Video Lectures (e-Resources):**

http://icas.bf.rtu.lv/doc/Book.pdf
http://www.adina.com/MITRES2_002S10_linear.pdf
https://www.edx.org/course/finite-element-method-fem-analysis-tsinghuax-70120073x

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

https://www.edx.org/course/hands-introduction-engineering-cornellx-engr2000x
http://nptel.ac.in/courses/112104115/
https://www.coursetalk.com/providers/mit/courses/finite-element-analysis-of-solids-and-fluids-i
https://online-learning.tudelft.nl/courses/linear-modeling-fem/

| Hydraulics & Pneumatics | | Semester | 7 |
|---|---|---|---|
| Course Code | **BME702** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3:0:2:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 hrs + 8-10 lab sessions | Total Marks | 100 |
| Credits | 04 | Exam Hours | 3 |
| Examination nature (SEE) | **Theory** | | |

**Course objectives:**

- To provide an insight into the capabilities and applications of hydraulic and pneumatic fluid power.
- To understand concepts and relationships surrounding force, pressure, energy and power in fluid power systems.
- To examine concepts cantering on sources of hydraulic power, rotary and linear actuators, distribution systems, hydraulic flow in pipes, and control components in fluid power systems.
- Exposure to build and interpret hydraulic and pneumatic circuits related to industrial applications.
- To familiarize with logic controls and trouble shooting

**Teaching-Learning Process (General Instructions)**

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

1. Intellectual skills; Concept of how to understand the procedures and codes for hydraulics and pneumatics
2. Cognitive strategy; Learner will use personal strategies to think and organise the course.
3. By creating learning activity to accomplish the course outcome.
4. By preparing ppt, showing animated videos and by giving some field-based activity.

**Module-1**

**Introduction to fluid power systems**

**Fluid power system:** components, advantages and applications. Transmission of power at static and dynamic states. Pascal's law and its applications.

**Fluids for hydraulic system:** types, properties, and selection. Additives, effect of temperature and pressure on hydraulic fluid. Seals, sealing materials, compatibility of seal with fluids. Fluid conditioning through filters, strainers; sources of contamination and contamination control; heat exchangers.

**Module-2**

**Pumps and Actuators**

**Pumps:** Classification of pumps, pumping theory of positive displacement pumps, construction and working of Gear pumps, Vane pumps, Piston pumps, fixed and variable displacement pumps, Pump performance characteristics, pump selection factors, problems on pumps.

**Actuators:** Classification cylinder and hydraulic motors, Hydraulic cylinders, single and double acting cylinder, mounting arrangements, cushioning, special types of cylinders, problems on cylinders. Construction and working of rotary actuators such as gear, vane, piston motors, and Hydraulic Motor. Theoretical torque, power, flow rate, and hydraulic motor performance; numerical problems. Symbolic representation of hydraulic actuators (cylinders and motors).

**Accumulators:** Types, selection/ applications of accumulators

**Module-3**

**Components and Hydraulic Circuit Design**

**Components:** Classification of control valves, Directional Control Valves-symbolic representation, constructional features of poppet, sliding spool, shuttle valve, and check valves.

**Pressure control valves -** types, direct operated types and pilot operated types.

**Flow Control Valves -**compensated and non-compensated FCV, needle valve, temperature compensated, pressure compensated, pressure and temperature compensated FCV, symbolic representation.

**Hydraulic Circuit Design:** Control of single and Double -acting hydraulic cylinder, regenerative circuit, pump unloading circuit, double pump hydraulic system, counterbalance valve application, hydraulic cylinder sequencing circuits, cylinder synchronizing circuit using different methods, hydraulic circuit for force multiplication; speed control of hydraulic cylinder metering in, metering out. Hydraulic circuit examples with accumulator.

**Module-4**

**Pneumatic Power Systems**

**Introduction to Pneumatic systems:** Pneumatic power system, advantages, limitations, applications, Choice of working medium. Characteristics of compressed air and air compressors. Structure of pneumatic control System, fluid conditioners-dryers and FRL unit.

**Pneumatic Actuators:** Linear cylinder – types of cylinders, working, end position cushioning, seals, mounting arrangements, and applications. Rotary cylinders- types, construction and application, symbols.

**Pneumatic Control Valves:** DCV such as poppet, spool, suspended seat type slide valve, pressure control valves, flow control valves, types and construction, use of memory valve, Quick exhaust valve, time delay valve.

**Module-5**

**Pneumatic Control Circuits**

**Simple Pneumatic Control:** Direct and indirect actuation pneumatic cylinders, speed control of cylinders - supply air throttling and exhaust air throttling.

**Signal Processing Elements:** Use of Logic gates - OR and AND gates in pneumatic applications. Practical examples involving the use of logic gates.

**Multi- Cylinder Application:** Coordinated and sequential motion control, motion and control diagrams. Signal elimination methods, Cascading method- principle, Practical application examples (up to two cylinders) using cascading method (using reversing valves).

**PRACTICAL COMPONENT OF IPCC** *(May cover all / major modules)*

| Sl.NO | Experiments |
|---|---|
| 1 | A] Study of Construction and working Hydraulic pumps and Pneumatic<br>B] Study of Hydraulic and Pneumatic valves.<br>C] Study of solenoid valves, limit switches. Pressure, flow control valve |
| 2 | Basic hydraulic circuit for the working of double acting cylinder and a hydraulic motor |
| 3 | Basic pneumatic circuit for the working of single and double acting cylinder. |
| 4 | Speed control circuits. Different Metering methods Inlet & outlet flow control (meter-in & meter-out circuit) |
| 5 | Circuits for the Use of different direction control valves and valve actuation in single And double acting cylinder, and multi actuation circuit. |
| 6 | Hydraulic Counter-balancing circuit. |

| | |
|---|---|
| 7 | Hydraulic or Pneumatic Regenerative circuit. |
| 8 | Hydraulic or Pneumatic Sequencing circuit. |
| 9 | **Can be Demo experiments for CIE**<br>Circuit with cam operated pilot valves operating a pilot operated 4way direction control Valve or proximity/ limit switches, solenoid operated 4way direction control valve for Auto reversing circuit. |
| 10 | **Can be Demo experiments for CIE**<br>Study of hydraulics and Pneumatics circuit, based on the industrial application. (At least one in each) |

**Course outcome (Course Skill Set)**

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

**CO1**: Identify and analyse the functional requirements of a fluid power transmission system for a given application.

**CO2**: Understand the operation, application, and maintenance of common fluid power components such as pumps, actuators and accumulators.

**CO3**: Design an appropriate hydraulic or pneumatic circuit or combination circuit like electro-hydraulics, electro- pneumatics for a given application.

**CO4**: Explain the pneumatic working media, applications and components of pneumatic system.

**CO5**: Develop a comprehensive circuit diagram by integrating the components selected for the given application using signal processing element.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**CIE for the theory component of the IPCC (maximum marks 50)**

- IPCC means practical portion integrated with the theory of the course.
- CIE marks for the theory component are **25 marks** and that for the practical component is **25 marks**.
- 25 marks for the theory component are split into **15 marks** for two Internal Assessment Tests (Two Tests, each of 15 Marks with 01-hour duration, are to be conducted) and **10 marks** for other assessment methods mentioned in 22OB4.2. The first test at the end of 40-50% coverage of the syllabus and the second test after covering 85-90% of the syllabus.
- Scaled-down marks of the sum of two tests and other assessment methods will be CIE marks for the theory component of IPCC (that is for **25 marks)**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the theory component of IPCC.

**CIE for the practical component of the IPCC**

- **15 marks** for the conduction of the experiment and preparation of laboratory record, and **10 marks** for the test to be conducted after the completion of all the laboratory sessions.
- On completion of every experiment/program in the laboratory, the students shall be evaluated including viva-voce and marks shall be awarded on the same day.
- The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to **15 marks**.
- The laboratory test **(duration 02/03 hours)** after completion of all the experiments shall be

conducted for 50 marks and scaled down to **10 marks.**

- Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for **25 marks**.
- The student has to secure 40% of 25 marks to qualify in the CIE of the practical component of the IPCC.

**SEE for IPCC**

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored by the student shall be proportionally scaled down to 50 Marks
5. **The theory portion of the IPCC shall be for both CIE and SEE, whereas the practical portion will have a CIE component only. Questions mentioned in the SEE paper may include questions from the practical component**.

**Suggested Learning Resources:**

**List of Text Books:**


1. Anthony Esposito, "Fluid Power with applications", Pearson edition, 2000.
2. Majumdar S.R., "Oil Hydraulics", Tala McGRaw HllL, 2002.
3. Majumdar S.R., "Pneumatic systems - Principles and Maintenance", Tata McGraw-Hill, New Delhi, 2005


**Reference Books:**


1. John Pippenger, Tyler Hicks, "Industrial Hydraulics", McGraw Hill International Edition, 1980.
2. Andrew Par, Hydraulics and pneumatics, Jaico Publishing House, 2005.
3. FESTO, Fundamentals of Pneumatics, Vol I, II and III.
4. Herbert E. Merritt, "Hydraulic Control Systems", John Wiley and Sons, Inc.
5. Thomson, Introduction to Fluid power, Prentcie Hall, 2004.
6. John Watton, "Fundamentals of fluid power control", Cambridge University press, 2012.


**Web links and Video Lectures (e-Resources):**

. **List of URLs, Text Books, Notes, Multimedia Content, etc**

1. https://nptel.ac.in/courses/112105047/
2. https://www.youtube.com/watch?v=8xd7cWyMrvE
3. https://nptel.ac.in/courses/105103096/
4. https://nptel.ac.in/courses/112105047/37

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

1. Basic laws of hydraulics and Power in hydraulic system used in fluid power system.
2. Prepare working models of hydraulic crane using waste injections used by doctors. ( Laboratory based)
3. Prepare report of agriculture equipment's working on hydraulics and pneumatics (Field based)
4. Collect technical specifications of pumps and motors and actuators. (Internet based)
5. Prepare visit report to observe use of pneumatic system used in automobile, Medical and agriculture (Field based)
6. Constructions and working of different types of circuits for various applications using hydraulic and pneumatic kit (portable).
7. Collections of animation videos of pumps, motors, actuators and Filters.( Software based)
8. Market survey of hydraulic oils used in hydraulic system. (Field based)

| CONTROL ENGINEERING | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME703** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | (3:0:0:0) | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 3 |
| Examination type (SEE) | **Theory** | | |

**Course objectives:**

- Study the fundamental concepts of Control systems and their mathematical modelling.
- Study the concept of time and frequency response of the system.
- Study the stability analysis of the control system.

**Teaching-Learning Process (General Instructions)**

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

1. Adopt teaching methods using PowerPoint presentation, Video demonstration.
2. Use of appropriate software tools to demonstrate the frequency response of the systems.
3. Adopt collaborative (Group Learning) learning in the class.
4. Adopt problem-based learning which fosters student's analytical skills and develop thinking skills.

**Module-1**

**Introduction:** Concept of automatic controls, Open loop and closed loop systems, Concepts of feedback, requirements of an ideal control system.

**Types of controllers:** Proportional, Integral Proportional Integral, Proportional Integral Differential controllers.

**Mathematical Models:** Transfer function models, models of mechanical systems, models of electrical circuits, models of thermal systems and models of hydraulic systems.

**Module-2**

**Block Diagrams and Signal Flow Graphs:** Transfer Functions definition, block representation of systems elements, reduction of block diagrams, Signal flow graphs: Mason's gain formula.

**System Compensation:** Series and feedback compensation, Lead compensator, Lag Compensator.

**Module-3**

**Transient and Steady State Response Analysis:** Introduction, test inputs, first order and second order system response to step, ramp and impulse inputs, concepts of time constant and its importance in speed of response. Steady state error, error constants.

**Module-4**

**System stability:** Routh's stability Criterion

**Root Locus Plots:** Definition of root loci, General rules for constructing root loci, Analysis using root locus plots.

**Module-5**

**Frequency Response Analysis:** Polar plots, Nyquist stability criterion, Bode Plots, Determination of phase margin and gain margin using Bode plot.

**Course outcome (Course Skill Set)**

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

1. Explain the control system and its types, control actions and develop system governing equations for physical models (Mechanical, Electrical, Thermal &Hydraulic Systems)
2. Analysis on the response of control system for standard test signals.
3. Apply block diagram & signal flow representations to obtain transfer function of control systems.
4. Analyse the stability of transfer functions in complex domain and frequency domain.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks.

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Books**


1. Modern Control Engineering, Katsuhiko Ogatta, Pearson Education, Fifth edition.
2. Modern Control Systems, Richard.C.Dorf and Robert.H.Bishop, Addison Wesley, Thirteenth Edition.
3. Control Systems Principles and Design, M.Gopal, Fourth Edition, TMH.
4. Automatic Control Systems, Benjamin C. Kuo, Farid Golnaraghi, McGraw Hill Education, Tenth Edition


**Web links and Video Lectures (e-Resources):**

- https://onlinecourses.nptel.ac.in/noc22_ee31/preview
- https://plc-coep.vlabs.ac.in/exp/pid-controller/index.html

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

- Frequency response of control system using MATLAB/SCILAB or any open-source software tools.

| Additive manufacturing | | Semester | 7 |
|---|---|---|---|
| Course Code | **BME714A** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3-0-0-0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 03 |
| Examination nature (SEE) | **Theory** | | |

**Course objectives:**

- To know the principal methods, areas of usage, possibilities and limitations of the Additive Manufacturing technologies.
- To be familiar with the characteristics of the different materials those are used in Additive Manufacturing.
- To know the principles of polymerization and powder metallurgy process, extrusion-based system printing processes, sheet lamination processes, beam deposition processes, direct write technologies Direct Digital Manufacturing.
- To get exposed to process selection, software issues and post processing.

**Teaching-Learning Process (General Instructions)**

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

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students' analytical skills and develops thinking skills such as evaluating, generalizing, and analysing information.

**Module-1**

**Introduction and basic principles:** Need for Additive Manufacturing, Generic AM process, stereo lithography or 3dprinting, rapid prototyping, the benefits of AM, distinction between AM and CNC machining, other related technologies- reverse engineering technology.

**Development of Additive Manufacturing Technology:** Introduction, computers, computer-aided design technology, other associated technologies, the use of layers, classification of AM processes, metals systems, hybrid systems, milestones in AM development.

**Additive Manufacturing Process chain:** Introduction, the eight steps in additive manufacture, variations from one AM machine to another, metal systems, maintenance of equipment, materials handling issues, design for AM, and application areas.

**Module-2**

**Photo polymerization processes:** Stereo lithography (SL), Materials, SL resin curing process, Micro- Stereo lithography, Process Benefits and Drawbacks, Applications of Photo polymerization Processes.

**Powder bed fusion processes:** Introduction, Selective laser Sintering (SLS), Materials, Powder fusion mechanism, SLS Metal and ceramic part creation, Electron Beam melting (EBM), Process Benefits and Drawbacks, Applications of Powder Bed Fusion Processes.

**Extrusion-based systems:** Fused Deposition Modelling (FDM), Principles, Materials, Plotting and path control, Bio-Extrusion, Process Benefits and Drawbacks, Applications of Extrusion-Based Processes.

**Module-3**

**Printing Processes:** evolution of printing as an additive manufacturing process, research achievements in printing deposition, technical challenges of printing, printing process modelling, material modification methods, three-dimensional printing, advantages of binder printing

**Sheet Lamination Processes:** Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), Gluing, Thermal bonding, LOM and UC applications.

**Beam Deposition Processes:** introduction, general beam deposition process, description material delivery, BD systems, process parameters, typical materials and microstructure, processing–structure–properties relationships, BD benefits and drawbacks.

**Direct Write Technologies:** Background, ink –based DW, laser transfer, DW thermals pray, DW beam deposition, DW liquid-phase direct deposition.

**Module-4**

**Guidelines for Process Selection:** Introduction, selection methods for apart, challenges of selection, example system for preliminary selection, production planning and control.

**Software issues for Additive Manufacturing:** Introduction, preparation of cad models – the STL file, problems with STL files, STL file manipulation.

**Post- Processing:** Support material removal, surface texture improvements, preparation for use as a pattern, property enhancements using non-thermal techniques and thermal techniques.

**Module-5**

**The use of multiple materials in additive manufacturing:** Introduction, multiple material approaches, discrete multiple material processes, porous multiple material processes, blended multiple material processes, commercial applications using multiple materials, future directions.

**AM Applications:** Examples for Aerospace, defence, automobile, Bio-medical and general engineering industries. Direct digital manufacturing: Align Technology, Siemens and Phonak, DDM drivers, manufacturing vs. prototyping, lifecycle costing, future of direct digital manufacturing.

**Course outcome (Course Skill Set)**

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

1. Demonstrate the knowledge of the broad range of AM processes, devices, capabilities and materials that are available.
2. Demonstrate the knowledge of the broad range of AM processes, devices, capabilities and materials that are available.
3. Describe the various software tools, processes and techniques that enable advanced/additive manufacturing.
4. Apply the concepts of additive manufacturing to design and create components that satisfy product development/prototyping requirements, using advanced/additive manufacturing devices and processes.
5. Elucidate characterization techniques in additive manufacturing.
6. Illustrate the latest trends and business opportunities in additive manufacturing.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Books**


1. Additive Manufacturing Technologies Rapid Prototyping to Direct Digital Manufacturing I. Gibson l D. W. Rosen l B. Stucker Springer New York Heidelberg Dordrecht, London ISBN: 978-1- 4419-1119-3 e-ISBN: 978- 1-4419- 1120-9 DOI 10.1007/978 -1-4419- 1120-9
2. "Rapid Prototyping: Principles & Applications Chua Chee Kai, Leong Kah Fai World Scientific 2003
3. Rapid Prototyping: Theory & Practice Ali K. Kamrani, Springer 2006 Emand Abouel Nasr,
4. Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling" D.T. Pham, S.S. Dimov Springer 2001
5. Rapid Prototyping: Principles and Applications in Manufacturing Rafiq Nooran John Wiley & Sons 2006
6. Additive Manufacturing Technology Hari Prasad, A.V. Suresh Cengage 2019
7. Understanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing Andreas Gebhardt


**Web links and Video Lectures (e-Resources):**

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

- Case studies
- Quiz
- Topic Seminar presentation
- Assignments

| Product Design and Management | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME714B** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3-0-0-0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 03 |
| Examination nature (SEE) | Theory | | |

**Course objectives:**

- Understanding the user-centred design process including form and colour theory.
- Understanding product metamorphosis, and ergonomics..
- Implement the principles of ergonomics and how to apply the principles to industrial design.
- Understand the importance and techniques of human biological data collection and experiments.
- Obtain a knowledge and ability towards Accident Investigation and Safety Management.

**Teaching-Learning Process (General Instructions)**

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

1. Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
2. Chalk and Talk method for Problem Solving.
3. Adopt flipped classroom teaching method.
4. Adopt collaborative (Group Learning) learning in the class.
5. Adopt Problem Based Learning (PBL), which fosters students' analytical skills and develops thinking skills such as evaluating, generalizing, and analysing information.

**Module-1**

**Introduction to Product Design:** Asimows Model: Definition of product design, Design by Evaluation, Design by Innovation, Essential Factors of Product Design, Flow and Value Addition in the Production-Consumption Cycle. The Morphology of Design (The seven Phase), Primary Design phase and flowcharting, role of Allowance, Process Capability.

**Module-2**

**Ergonomics and Industrial Design:** Introduction -general approach to the man- machine relationship- workstation design-working position.

**Ergonomics and Production:** Ergonomics and product design –ergonomics in automated systems- expert systems for ergonomic design. Anthropometric data and its applications in ergonomic, design- limitations of anthropometric data use of computerized database. Case study.

**Module-3**

**Aesthetic Concepts:** Concept of unity- concept of order with variety - concept of purpose style and environment- Aesthetic expressions. Style components of style- house style, observation style in capital goods, case study.

**Module-4**

**Visual Effects of Line and Form:** The mechanics of seeing- psychology of seeing general influences of line and form.

**Colour:** Colour and light -colour and objects- colour and the eye -colour consistency- colour terms- reactions to colour and colour continuation -colour on engineering equipment's.

**Module-5**

**Ergonomics of Technology Management:** Office Systems and Ergonomics, Consumer Ergonomics, Ergonomics Quality and Safety, Quality of Life

**Course outcome (Course Skill Set)**

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

1. Illustrate the concept of product design and the ergonomics.
2. Design the various controls and displays by knowing the anthropometric data.
3. Charaterize the psychology of visuals effects.
4. Evaluate the different colour combinations for optimal design of engineering equipments.
5. Understand the importance of environmental factors and aesthetics in industrial design and management.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Books**

1. Human Factors in Engineering and Design By Sanders & Mccormick (McGrawHill Publication)
2. Occupational Ergonomics – Principles and Applications By Tayyari & Smith (Chapman & Hall Publication)
3. The Power of Ergonomics as a Competitive Strategy By Gross & Right (Productivity Press)
4. Industrial Design for Engineers - Mayall W.H. - London Hiffee books Ltd. -1988.

5. Applied Ergonomics Hand Book - Brain Shakel (Edited) - Butterworth scientific. London - 1988. 6. Introduction to Ergonomics - R. C. Bridger - McGraw Hill Publications - 1995.
6. Human Factor Engineering - Sanders & McCormick – McGraw Hill Publications – 6th edition, 2002.
7. Ulrich, Karl T, Eppinger, Steven D, 'Product Design and Development', McGraw-Hill, 2004.
8. Bridger RS, 'Introduction to Human Factors & Ergonomics', Fourth Edition, Taylor & Francis, 2010.
9. Dul. J and Weerdmeester B, 'Ergonomics for beginners, a quick reference guide, Taylor & Francis, 2008

**Web links and Video Lectures (e-Resources):**

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

- Anthropometry
- Hand strength and Back strength
- Measurement of Environmental Factors
- Grip Strength – Hand and Pinch

| IC ENGINES | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME714C** | CIE Marks | 50 |
| Teaching Hours/Week (L:T:P: S) | 3:0:0:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 hours | Total Marks | 100 |
| Credits | 03 | Exam Hours | 03 |
| Examination type (SEE) | Theory | | |

**Course objectives:**

- To give an overview of Internal Combustion Engines, their classification, applications, operation and processes.
- To describe combustion phenomena in IC engines
- To give complete knowledge of type of fuels used in IC engines and the fuel supply systems.
- To explain the different performance analysis of IC engines
- To explain the effects of exhaust emission on human health and various pollution norms

**Teaching-Learning Process (General Instructions)**

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

- Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
- Arrange visits to show the live working models other than laboratory topics.
- Adopt collaborative (Group Learning) Learning in the class.
- Adopt Problem Based Learning (PBL), which foster students' Analytical skills and develops
- Thinking skills such as evaluating, generalizing, and analyzing information.

**Module-1**

**I.C. Engines** - Classification based on multi cylinder engine, firing order, selection criteria of IC engines based on application, materials and manufacturing processes of ICE components.

**Thermodynamic cycle analysis**– Deviation from ideal processes. Effect of chemical equilibrium and variable specific heats. Effect of air fuel ratio and exhaust gas dilution. Calculation of combustion temperatures. Use of combustion charts. Simple. numerical problems.

**Module-2**

**Carburetion and combustion process in S.I. engines:** Mixture requirements in S.I engine. Simple Carburettor and its limitations. Knock fee and knocking combustion-Theories of combustion process in S.I. engines. Effect of Knock on engine performance. Effect of operating variables on knocking. Knock rating of fuels-octane number. HUCR values. Anti knock agents - Pre-ignition - Post ignition.

**Combustion in C.I. engines:** Ricardo's three stages of combustion process in C.I. engines. Delay period & factors affecting delay period. Diesel knock- Methods of controlling diesel knock. Knock rating of Diesel fuels.

**Module-3**

**Combustion chambers:** Requirements of combustion chambers. Features of different types of combustion chambers system for S.I. engine. I-head, F-head combustion chambers. C.I. engine combustion chambers-Air swirl turbulence-M. type combustion chamber. Comparison of various types of combustion chambers.

**Fuels:** Hydro carbons - chemical structure-influence of chemical structure on knock alternative fuels-Alcohols-vegetable oils- Bio gas as Diesel engine fuels.

**Module-4**

**Fuel injection systems:** Diesel injection systems-jerk pump injectors Nozzles of different types-Petrol injection systems for S.I. engines-Electronic fuel injection system. Cooling system- Water cooling, air cooling & liquid cooling-role of thermostats-radiator construction.

**Module-5**

**Modern developments**: Turbo charging and super charging of I.C.Engines, Stratified charge engines (Lean burned SI engine) Multi fuel engines, Rotary piston engine, Two injector engines Pilot ignition engine, all ceramic swirl chamber engines.

**Emission regulation and Control systems**: Mechanism of pollutant formation. Total emission control package thermal reactor package-catalytic converter package-control of NOX -Exhaust gas recirculation-Water injection.

**Course outcome (Course Skill Set)**

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

CO1: Understand various types of I.C. Engines, Cycles of operation and Identify fuel metering, fuel supply systems for different types of engines.

CO2: Explain the operating characteristics and thermodynamic analysis of common internal combustion engine cycles.

CO3: Understand combustion phenomena in SI and CI engines and Analyze the effect of various operating variables on engine performance.

CO4: To analyze the combustion process of common fuels.

CO5: Understand the conventional and non-conventional fuels and effects of emission formation of IC engines, its effects and the legislation standards.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks.

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Test Books**

1. Heywood J.B., "Internal combustion Engine Fundamentals", McGraw Hill, 1988
2. Domkundwar V.M., "Internal combustion Engines", 6th Ed.Tata McGraw Hill Publishing Co.
3. PulkrabekW , "Internal combustion engines", 8th Ed.; Dhanpat Rai publication.,2003,

**REFERENCE BOOKS**

1. Ganesan V , "Internal combustion Engine and Air Pollution", Intext Educational Pub,1974.
2. Ferguson and Kirkpatric; Internal Combustion Engines, by Wiley publishers.

**Web links and Video Lectures (e-Resources):**

- https://youtu.be/vIJ50aUiBgM
- https://youtu.be/fTAUq6G9apg
- https://youtu.be/_Ko0jJsQWxA
- https://youtu.be/GR0oI5sDCww
- https://youtu.be/sz8cqygvPC4
- https://youtu.be/GWav5n1x6hQ

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

1. Demonstration of IC engine.
2. Overhauling of IC engine (assembling and disassembling of 4-cylinder diesel jeep engine).
3. Emission test of IC engine vehicles.
4. Video demonstration of latest trends in IC engine.
5. Visit to nearest automotive sales and service shop.

| Cryogenics | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME714D** | CIE Marks | 50 |
| Teaching Hours/Week (L:T:P: S) | 3-0-0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 3 |
| Examination type (SEE) | Theory/practical/Viva-Voce /Term-work/Others | | |

Course Objectives:

1. To understand cryogenic system and gas liquefaction system
2. To analyze gas cycle cryogenic refrigeration system
3. To Comprehend gas separation and gas purification system
4. To have detailed knowledge of vacuum technology, insulation, storage of cryogenic liquids
5. To study applications of cryogenics and to embark on cryogenic fluid

**Teaching-Learning Process (General Instructions)**

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

- Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations.
- Chalk and Talk method for Problem Solving.
- Adopt collaborative (Group Learning) learning in the class.

**Module-1**

**Introduction to Cryogenic Systems**: Cryogenic propellants and its applications, liquid hydrogen, liquid nitrogen, and liquid Helium The thermodynamically Ideal system Production of low temperatures – Joule Thompson Effect, Adiabatic expansion. Gas Liquefaction Systems: Liquefaction systems for Air Simple Linde –Hampson System, Claude System, Heylndt System, Dual pressure, Claude. Liquefaction cycle Kapitza System. Comparison of Liquefaction Cycles Liquefaction cycle for hydrogen, helium and Neon, Critical components of liquefaction systems.

**Module-2**

**Gas Cycle Cryogenic Refrigeration Systems**: Classification of Cryo coolers, Stirling cycle Cryo – refrigerators, Ideal cycle – working principle. Schmidt‘s analysis of Stirling cycle, Various configurations of Stirling cycle refrigerators, Integral piston Stirlingcryo-cooler, Free displacer split type StirlingCryo coolers, Gifford Mcmahon Cryo- refrigerator, Pulse tube refrigerator, Solvay cycle refrigerator, Vuillimier refrigerator, Cryogenic regenerators.

**Module-3**

Gas Separation and Gas Purification Systems Thermodynamic ideal separation system, Properties of mixtures, Principles of gas separation, Linde single column air separation. Linde double column air separation, Argon and Neon separation systems. Ultra Low Temperature Cryo – Refrigerators Magneto Caloric Refrigerator 3He-4He Dilution refrigerator. Pomeranchuk cooling. Measurement systems for low temperatures, Temperature measurement at low temperatures, Resistance thermometers, Thermocouples, Thermistors, Gas Thermometry. Liquid level sensors.

**Module-4**

Vacuum Technology Vacuum Technology: Fundamental principles. Production of high vacuum, Mechanical vacuum pumps, Diffusion pumps, Cryo-pumping, Measurement of high vacuum level. Cryogenic Insulation: Heat transfer due to conduction, Evacuated porous insulation Powder & Fibers Opacified powder insulation, Gas filled powders & Fibrous materials Multilayer super-insulation, Composite insulation

**Module-5**

Cryogenic Fluid Storage and Transfer Systems Design of cryogenic fluid storage vessels, Inner vessel, Outer Insulation, Suspension system, Fill and drain lines. Cryogenic fluid transfer, External pressurization, Self-pressurization, Transfer pump. Application of Cryogenic Systems Cryogenic application for food preservation – Instant Quick Freezing Techniques Super conductive devices, Cryogenic applications for space technology. Application of cryogenic systems, super conducting devices, space technology, cryogenic in biology and medicine.

**Course outcome (Course Skill Set)**

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

1. Understand the cryogenic system.
2. Demonstrate the complete knowledge of cryogenic refrigeration system
3. Design gas separation and gas purification systems
4. Solve the problem in , insulation, storage of cryogenic liquids
5. Apply cryogenic in various areas and to be able take up research in cryogenics

## 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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks.

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Text Books**

1. Cryogenic Systems – R.F. Barron
2. Cryogenic Engineering – R.B. Scott – D.VanNostrand Company, 1959

**REFERENCE BOOKS**:

1. Cryogenic Process Engineering – K.D. Timmerhaus and T.M. Flynn, Plenum Press, New York,1989
2. High Vacuum Technology – A. Guthree – New Age International Publication
3. Experimental Techniques in Low Temperature Physics – G.K. White – Oxford University Press,

**Web links and Video Lectures (e-Resources):**

- VTU-E-learning.
- NPTEL

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

- Quiz
- Topic Seminar presentation
- Assignments

| Introduction to NON-TRADITIONAL MACHINING | | Semester | VII |
|---|---|---|---|
| Course Code | **BME755A** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3:0:0:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 hrs | Total Marks | 100 |
| Credits | 03 | Exam Hours | 3 |
| Examination type (SEE) | Theory | | |

**Course objectives:**

To learn various concepts related to modern machining processes & their applications.

- To appreciate the differences between conventional and non-conventional machining processes.
- To acquire a functional understanding of non-traditional manufacturing equipment.
- To know about various process parameters and their influence on performance and their applications.
- To impart knowledge on various types of energy involved in non-traditional machining processes.

**Teaching-Learning Process (General Instructions)**

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

- Adopt different types of teaching methods to develop the outcomes through PowerPoint presentations and Video demonstrations or Simulations.
- Arrange visits to show the live working models other than laboratory topics.
- Adopt collaborative (Group Learning) Learning in the class.
- Adopt Problem Based Learning (PBL), which foster students' Analytical skills and develops Thinking skills such as evaluating, generalizing, and analyzing information.

**Module-1**

Introduction to Non-traditional machining, Need for Non-traditional machining process, Comparison between traditional and non-traditional machining, general classification Non-traditional machining processes, classification based on nature of energy employed in machining, selection of non-traditional machining processes, Specific advantages, limitations and applications of non-traditional machining processes.

**Module-2**

**Ultrasonic Machining (USM**): Introduction, Equipment and material process, Effect of process parameters: Effect of amplitude and frequency, Effect of abrasive grain diameter, effect of slurry, tool & work material. Process characteristics: Material removal rate, tool wear, accuracy, surface finish, applications, advantages & limitations of USM.

**Abrasive Jet Machining (AJM):**

Introduction, Equipment and process of material removal, process variables: carrier gas, type of abrasive, work material, stand-off distance (SOD). Process characteristics-Material removal rate, Nozzle wear, accuracy & surface finish. Applications, advantages & limitations of AJM.

**Module-3**

**ELECTROCHEMICAL MACHINING (ECM):** Introduction, Principle of electro chemical machining, ECM equipment, elements of ECM operation, Chemistry of ECM. ECM Process characteristics: Material removal rate, accuracy, surface finish. Process parameters: Current density, Tool feed rate, Gap between tool & work piece, velocity of electrolyte flow, type of electrolyte, its concentration temperature, and choice of electrolytes. ECM Tooling: ECM tooling technique & example, Tool & insulation materials. Applications ECM: Electrochemical grinding and electrochemical honing process. Advantages, disadvantages and application of ECG, ECH.

**CHEMICAL MACHINING (CHM):** Elements of the process, Resists (maskants), Etchants. Types of chemical machining process-chemical blanking process, chemical milling process. Process

characteristics of CHM: material removal rate, accuracy, surface finish, advantages, limitations and applications of chemical machining process.

**Module-4**

**ELECTRICAL DISCHARGE MACHINING (EDM):** Introduction, mechanism of metal removal, EDM equipment: spark erosion generator (relaxation type), dielectric medium-its functions & desirable properties, electrode feed control system. Flushing types; pressure flushing, suction flushing, side flushing, pulsed flushing.

**EDM process parameters:** Spark frequency, current & spark gap, surface finish, Heat Affected Zone. Advantages, limitations & applications of EDM, Electrical discharge grinding, Traveling wire EDM. PLASMA ARC MACHINING (PAM): Introduction, non-thermal generation of plasma, equipment mechanism of metal removal, Plasma torch, process parameters, process characteristics. Safety precautions. Safety precautions, applications, advantages and limitations

**Module-5**

**LASER BEAM MACHINING (LBM):** Introduction, generation of LASER, Equipment and mechanism of metal removal, LBM parameters and characteristics, Applications, Advantages & limitations.

**ELECTRON BEAM MACHINING (EBM):** Introduction, Principle, equipment and mechanism of metal removal, applications, advantages and limitations.

**Course outcome (Course Skill Set)**

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

CO1: Understand the compare traditional and non-traditional machining process and recognize the need for Non- traditional machining process.

CO2: Explain the constructional features, performance parameters, process characteristics, applications, advantages and limitations of USM, AJM and WJM.

CO3: Identify the need of Chemical and electro-chemical machining process along with the constructional features, process parameters, process characteristics, applications, advantages and limitations.

CO4: Understand the constructional feature of the equipment, process parameters, process characteristics, applications, advantages and limitations EDM & PAM.

CO5: Understand the LBM equipment, LBM parameters, and characteristics. EBM equipment and mechanism of metal removal, applications, advantages and limitations LBM & EBM.

## 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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB2.4, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks.

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Text Books:**

1. Modern Machining Process by P.C Pandey and H S Shah, McGraw Hill Education India Pvt. Ltd. 2000
2. Production technology, HMT, McGraw Hill Education India Pvt. Ltd 2001

**Reference Books:**

1. New Technology, Dr. Amitabha Bhattacharyya, The Institute of Engineers (India) 2000
2. Modern Machining process, Aditya, 2002

**Web links and Video Lectures (e-Resources):**

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

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| Basics of Hydraulics & Pneumatics | | Semester | 7 |
|---|---|---|---|
| Course Code | **BME755B** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3:0:2:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 3 |
| Examination nature (SEE) | Theory | | |

**Course objectives:**

- To provide an insight into the capabilities and applications of hydraulic and pneumatic fluid power.
- To understand concepts and relationships surrounding force, pressure, energy and power in fluid power systems.
- To examine concepts cantering on sources of hydraulic power, rotary and linear actuators, distribution systems, hydraulic flow in pipes, and control components in fluid power systems.
- Exposure to build and interpret hydraulic and pneumatic circuits related to industrial applications.
- To familiarize with logic controls and trouble shooting

**Teaching-Learning Process (General Instructions)**

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

1. Intellectual skills; Concept of how to understand the procedures and codes for hydraulics and pneumatics
2. Cognitive strategy: Learner will use personal strategies to think and organise the course.
3. By creating learning activity to accomplish the course outcome.
4. By preparing ppt, showing animated videos and by giving some field-based activity.

**Module-1**

**Introduction to fluid power systems**

**Fluid power system:** components, advantages and applications. Transmission of power at static and dynamic states. Pascal's law and its applications.

**Fluids for hydraulic system:** types, properties, and selection. Additives, effect of temperature and pressure on hydraulic fluid. Seals, sealing materials, compatibility of seal with fluids. Fluid conditioning through filters, strainers; sources of contamination and contamination control

**Module-2**

**Pumps and actuators**

**Pumps:** Classification of pumps, pumping theory of positive displacement pumps, construction and working of Gear pumps, Vane pumps, Piston pumps, fixed and variable displacement pumps, Pump performance characteristics, pump selection factors,

**Actuators:** Classification cylinder and hydraulic motors, Hydraulic cylinders, single and double acting cylinder, cushioning, special types of cylinders, Construction and working of rotary actuators such as gear, vane, piston motors, and Hydraulic Motor. Symbolic representation of hydraulic actuators (cylinders and motors).

**Accumulators:** Types, selection/ applications of accumulators

**Module-3**

**Components and hydraulic circuit design**

**Components:** Classification of control valves, Directional Control Valves-symbolic representation, constructional features of poppet, sliding spool, shuttle valve, and check valves.

**Pressure control valves -** types, direct operated types and pilot operated types.

**Flow Control Valves -**compensated and non-compensated FCV, needle valve, temperature compensated, pressure compensated, pressure and temperature compensated FCV, symbolic representation.

**Hydraulic Circuit Design:** Control of single and Double -acting hydraulic cylinder, regenerative circuit,

pump unloading circuit, double pump hydraulic system, counterbalance valve application, hydraulic cylinder sequencing circuits, cylinder synchronizing circuit using different methods, speed control of hydraulic cylinder metering in, metering out. Hydraulic circuit examples with accumulator.

**Module-4**

**Module4: Pneumatic power systems**

**Introduction to Pneumatic systems:** Pneumatic power system, advantages, limitations, applications, Choice of working medium. Characteristics of compressed air and air compressors. Structure of pneumatic control System, fluid conditioners-dryers and FRL unit.

**Pneumatic Actuators:** Linear cylinder – types of cylinders, working, end position cushioning, seals, mounting arrangements, and applications.

**Pneumatic Control Valves:** DCV such as poppet, spool, suspended seat type slide valve, pressure control valves, flow control valves, types and construction, use of memory valve, Quick exhaust valve, time delay valve.

**Module-5**

**Module5: Pneumatic control circuits**

**Simple Pneumatic Control:** Direct and indirect actuation pneumatic cylinders, speed control of cylinders - supply air throttling and exhaust air throttling.

**Signal Processing Elements:** Use of Logic gates – OR, AND, NOT and NAND gates in pneumatic applications. Practical examples involving the use of logic gates.

**Multi- Cylinder Application:** Coordinated and sequential motion control, motion and control diagrams. Signal elimination methods, Cascading method- principle, Practical application examples (up to two cylinders).

**Course outcome (Course Skill Set)**

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

CO1: Identify and analyse the functional requirements of a fluid power transmission system for a given application.

CO2: Understand the operation, application, and maintenance of common fluid power components such as pumps, actuators and accumulators.

CO3: Design an appropriate hydraulic or pneumatic circuit or combination circuit like electro-hydraulics, electro- pneumatics for a given application.

CO4: understand the pneumatic working media, applications and components of pneumatic system.

CO5: Develop a comprehensive circuit diagram by integrating the components selected for the given application using signal processing element.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assignment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

**Internal Assessment Test 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 course (**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.
3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**List of Text Books:**

1. Anthony Esposito, "Fluid Power with applications", Pearson edition, 2000.
2. Majumdar S.R., "Oil Hydraulics", Tala McGRaw HllL, 2002.
3. Majumdar S.R., "Pneumatic systems - Principles and Maintenance", Tata McGraw-Hill, New Delhi, 2005

**Reference Books:**

1. John Pippenger, Tyler Hicks, "Industrial Hydraulics", McGraw Hill International Edition, 1980.
2. Andrew Par, Hydraulics and pneumatics, Jaico Publishing House, 2005.
3. FESTO, Fundamentals of Pneumatics, Vol I, II and III.
4. Herbert E. Merritt, "Hydraulic Control Systems", John Wiley and Sons, Inc.
5. Thomson, Introduction to Fluid power, Prentcie Hall, 2004
6. John Watton, "Fundamentals of fluid power control", Cambridge University press, 2012.

**Web links and Video Lectures (e-Resources):**

. **List of URLs, Text Books, Notes, Multimedia Content, etc**

1. https://nptel.ac.in/courses/112105047/
2. https://www.youtube.com/watch?v=8xd7cWvMrvE
3. https://nptel.ac.in/courses/105103096/
4. https://nptel.ac.in/courses/112105047/37

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

| OPERATIONS RESEARCH | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME755C** | CIE Marks | 50 |
| Teaching Hours/Week (L: T:P: S) | 3:0:0:0 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 03 |
| Examination type (SEE) | Theory | | |

**Course objectives:**

- To introduce students to use quantitative methods and techniques for effective decisions–making;
- Mathematical model formulation and solving business decision problems.

**Teaching-Learning Process (General Instructions)**

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

1. Use of Chalk and Talk method
2. Video lectures, lecture projections in class
3. Individual and Group assignments

**Module-1**

**Introduction**: Evolution of OR, definition of OR, scope of OR, application areas of OR, steps (phases) in OR study, characteristics and limitations of OR, models used in OR, linear programming (LP) problem-formulation and solution by graphical method. The simplex method using slack variables.

**Module-2**

**Transportation Problem**: Formulation of transportation problem, types, initial basic feasible solution using different methods, optimal solution by MODI method, degeneracy in transportation problems, application of transportation problem concept for maximization cases. **Assignment Problem:** Formulation, types, application to maximization cases and travelling salesman problem.

**Module-3**

**PERT-CPM Techniques**: Introduction, network construction - rules, Fulkerson's rule for numbering the events, AON and AOA diagrams; Critical path method to find the expected completion time of a project, floats; PERT for finding expected duration of an activity and project, determining the probability of completing a project, predicting the completion time of project; crashing of simple projects.

**Module-4**

**Game Theory**: Formulation of games, types, solution of games with saddle point, graphical method of solving mixed strategy games, dominance rule for solving mixed strategy games.

**Queuing Theory**: Queuing systems and their characteristics, Pure-birth and Pure-death models (only equations), empirical queuing models (M/M/1 model).

**Module-5**

**Sequencing:** Basic assumptions, sequencing 'n' jobs on single machine using priority rules, sequencing using Johnson's rule-'n' jobs on 2 machines, 'n' jobs on 3 machines, 'n' jobs on 'm' machines. Sequencing 2 jobs on 'm' machines using graphical method.

**Course outcome (Course Skill Set)**

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

- Understand the importance, phases, & limitations of operations research.
- Formulate a real-world problem in OR as a mathematical model.
- Apply PERT and CPM network techniques to solve project management problems.
- Choose appropriate OR models to solve transportation problem, assignment model, game theory, queuing theory and sequencing models.

**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 out of 50) and for the SEE minimum passing mark is 35% of the maximum marks (18 out of 50 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 a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

**Continuous Internal Evaluation:**

- The CIE is the sum of Average of Two Internal Assessment Tests each of 25 marks and Any two Assessment methods for 25 marks.
- The first test will be administered after 40-50% of the syllabus has been covered, and the second test will be administered after 85-90% of the syllabus has been covered
- Any two assessment methods mentioned in the 22OB4.2, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
- For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment for a total of 50 marks.

**Internal Assessment Test 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 course (**duration 03 hours).**

- The question paper will have ten questions. Each question is set for 20 marks.
- 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.
- Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Books**


1. **Operations Research,** P K Gupta and D S Hira, 7th Edition, Chand Publications, New Delhi
2. **Operations Research,** R. Panneerselvam, 3rd Edition, PHI
3. **Operations Research Theory, Methods & Applications,** S.D. Sharma, Kedarnath Ramanath & Co, 2012.
4. **Operations Research**, A M Natarajan, P Balasubramani, Pearson Education, 2005
5. **Introduction to Operations Research**, Hillier and Lieberman, 8th Edn, McGraw Hill,


**Web links and Video Lectures (e-Resources):**

- https://nptel.ac.in/courses/112106134

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

- Use appropriate software tools to solve real world problems Operations Research for different businesses

| NON-CONVENTIONAL ENERY RESOURCES | | Semester | 7th |
|---|---|---|---|
| Course Code | **BME755D** | CIE Marks | 50 |
| Teaching Hours/Week (L:T:P: S) | 03 | SEE Marks | 50 |
| Total Hours of Pedagogy | 40 | Total Marks | 100 |
| Credits | 03 | Exam Hours | 03 |
| Examination type (SEE) | Theory | | |

**Course objectives:**

- To introduce the concepts of solar energy, its radiation, collection, storage and application.
- To introduce the concepts and applications of Wind energy, Biomass energy, Geothermal energy and Ocean energy as alternative energy sources.
- To explore society's present needs and future energy demands.
- To examine energy sources and systems, including fossil fuels and nuclear energy, and then focus on alternate, renewable energy sources such as solar, biomass (conversions), wind power, geothermal, etc.
- To get exposed to energy conservation methods.

**Module-1**

**Introduction**:

Energy source, India's production and reserves of commercial energy sources, need for non-conventional energy sources, energy alternatives, solar, thermal, photovoltaic. Waterpower, wind biomass, ocean temperature difference, tidal and waves, geothermal, tar sands and oil shale, nuclear (Brief descriptions); advantages and disadvantages, comparison (Qualitative and Quantitative).

**Solar Radiation Measurement of Solar Radiation**

Solar Radiation: Extra-Terrestrial radiation, spectral distribution of extra-terrestrial radiation, solar constant, solar radiation at the earth's surface, beam, diffuse and global radiation, solar radiation data. Measurement of Solar Radiation: Pyrometer, shading ring pyrheliometer, sunshine recorder, schematic diagrams and principle of working.

**Module-2**

**Solar Radiation Geometry:** Flux on a plane surface, latitude, declination angle, surface azimuth angle, hour angle, zenith angle, solar altitude angle expression for the angle between the incident beam and the normal to a plane surface (No derivation) local apparent time. Apparent motion of sum, day length, numerical examples.

**Radiation Flux on a Tilted Surface Solar Thermal Conversion**

Radiation Flux on a Tilted Surface: Beam, diffuse and reflected radiation, expression for flux on a tilted surface (no derivations) numerical example. Solar Thermal Conversion: Collection and storage, thermal collection devices, liquid flat plate collectors, solar air heaters concentrating collectors (cylindrical, parabolic, paraboloid) (Quantitative analysis); sensible heat storage, latent heat storage, application of solar energy water heating. Space heating and cooling, active and passive systems, power generation, refrigeration. Distillation (Qualitative analysis) solar pond, principle of working, operational problems**.**

**Module-3**

**Performance Analysis of Liquid Flat Plate Collectors**

General description, collector geometry, selective surface (qualitative discussion) basic energy-balance equation, stagnation temperature, transmissivity of the cover system, transmissivity – absorptivity product, numerical examples. The overall loss coefficient, correlation for the top loss coefficient, bottom and side loss coefficient, problems (all correlations to be provided). Temperature distribution between the collector tubes, collector heat removal factor, collector efficiency factor and collector flow factor, mean plate temperature, instantaneous efficiency (all expressions to be provided). Effect of various parameters on the collector performance; collector orientation, selective surface, fluid inlet temperature, number covers, dust.

**Photovoltaic Conversion**

Photovoltaic Conversion: Description, principle of working and characteristics, applications.

**Module-4**

**Wind Energy:**

Properties of wind, availability of wind energy in India, wind velocity and power from wind; major problems associated with wind power, wind machines; Types of wind machines and their characteristics, horizontal and vertical axis windmills, elementary design principles; coefficient of performance of a windmill rotor, aerodynamic considerations of windmill design, numerical examples.

**Tidal Power:**

Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, limitations.

**Ocean Thermal Energy Conversion:**

Principle of working, Rankine cycle, OTEC power stations in the world, problems associated with OTEC.

**Module-5**

**Hydrogen Energy:**

Properties of Hydrogen with respected to its utilization as a renewable form of energy, sources of hydrogen, production of hydrogen, electrolysis of water, thermal decomposition of water, thermo chemical production bio-chemical production. Storage & Transportation Methods: Gaseous, cryogenic and metal hydrides, application of hydrogen, domestic and industrial safe burning of hydrogen.

**Geothermal Energy Conversion:**

Principle of working, types of geothermal station with schematic diagram, geothermal plants in the world, problems associated with geothermal conversion, scope of geothermal energy.

**Energy from Biomass:**

Photosynthesis, photosynthetic oxygen production, energy plantation, biogas production from organic wastes by anaerobic fermentation, description of bio-gas plants, transportation of biogas, problems involved with bio-gas production, application of bio-gas, application of bio-gas in engines, advantages.

**Course outcome (Course Skill Set)**

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

1. Describe the environmental aspects of non-conventional energy resources in Comparison with various conventional energy systems, their prospects and limitations, the need of renewable energy resources, historical and latest developments.
2. Describe the use of solar energy and the various components used in the energy production with respect to applications like-heating, cooling, desalination, power generation, drying, cooking etc.
3. Explain the need of Wind Energy and the various components used in energy generation and know the classifications.
4. Understand the concept of Biomass energy resources and their classification, types of biogas Plants- applications.
5. Compare the working principles of fuel cells, wave power, tidal power and geothermal principles and applications.

**Assessment Details (both CIE and SEE)**

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3. The students have to answer 5 full questions, selecting one full question from each module.
4. Marks scored shall be proportionally reduced to 50 marks

**Suggested Learning Resources:**

**Books**


1. Non-Convention Energy Resources by B H Khan, 3rd Edition ,McGraw Hill Education (India) Pvt. Ltd.
2. Non-Conventional Energy Sources by G.D Rai, Khanna Publishers (2003).
3. Solar Energy by Subhas P Sukhatme, 2nd Edition Tata Mcgraw Hill (1996).
4. Renewable energy sources and Conversion technology by N.K.Bansal, Manfred Kleeman and Mechael Meliss, Tata Mcgraw Hill (2004).


**Web links and Video Lectures (e-Resources):**

- https://www.youtube.com/watch?v=ybZbwKIB1Ic
- https://onlinecourses.nptel.ac.in/noc23_ge04/preview.
- https://www.youtube.com/watch?v=LOVZE9WalRE Fundamentals of Photovoltaics
- https://www.youtube.com/watch?v=BcVzc6IGwS0 This lecture explores factors that affect the amount of sunlight reaching Earth's surface: e.g. orbit and tilt, scattering in the atmosphere, weather, and diffuse vs. direct sunlight.

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

- Visit to Nearby power Plants, Solar Plants , Wind Mills etc
- Case studies and Quiz.
- Topic Seminar presentation.