Bharatiya Vidya Bhavan's
SARDAR PATEL COLLEGE OF ENGINEERING
(Government Aided Autonomous Institute under Mumbai University)
Andheri (W) Mumbai - 400058

Bachelor of Technology

Mechanical Engineering Program

Regulation -2023

Course Contents

Third Year of Mechanical Engineering

(Applicable for Working Professional also)

Semester – V & VI

Academic Year – 2025-26

Sardar Patel College of Engineering, Andheri (West), Mumbai 400058
Course Contents for Semesters – V & VI (BTech Mechanical), AY: 2025-26
(Under Regulations 2023)

List of the Courses

PC-BTM501 Heat and Mass Transfer

Course Pre-requisites: Thermodynamics, Fluid Mechanics and Engineering Mathematics

Course Objectives:

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

1. Identify different heat and mass transfer modes occurring in thermal systems.
2. Analyze steady and transient conduction problems.
3. Learn the fundamentals of convective heat transfer
4. Understand the methods of analyzing a heat exchanger.
5. Learn about the basic concept of mass transfer

Course Outcomes:

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

1. Understand different modes of heat transfer and estimate the heat transfer by using classical laws.
2. Apply the knowledge of mathematics, science and heat transfer to develop mathematical models.
3. Analyze heat exchange through radiation.
4. Analyze and evaluate heat transfer in context with conduction, convection and heat exchangers

Course Contents:

Module No.	Details	Hrs.
1	**Basic Concepts:** Understanding generalized energy equation in the mathematical form, Modes of heat transfer, its mechanism and mathematical models.	05
2	**Conduction:** General conduction equation in cartesian, cylindrical and spherical Coordinates (Only use of equations and no derivations) Steady state solution of one-dimensional conduction equation for isotropic materials of various configurations such as plane wall, plane composite wall, cylindrical and spherical composite walls.	08
3	**Transient Conduction:** Lumped capacity method, Distributed parameter treatment.	04
4	**Fundamental of Convection:** Natural and Forced convection, hydrodynamic and thermal boundary layers. Heat transfer coefficient. Effect of various parameters such as physical properties of the fluid, system geometry, fluid flow etc. on heat transfer coefficient. Physical significance of dimensionless numbers such as Nusselt's Number, Grashoffs Number, Prandtl's Number, Reynolds Number and Stanton's Number. Empirical relations for free and forced convection for standard cases.	08
5	**Fundamental of Radiation:**	06

	Origin of thermal radiation, Concept of black body and grey body. Emissive power and Emissivity. Basic laws of Radiation: Planck's law, Radiation heat exchange between two black bodies. Electrical network analogy for radiation heat exchange between two and three grey bodies.	
6	**Heat Exchangers:** Classification of heat exchangers. Logarithmic Mean Temperature Difference, Correction factor and effectiveness of heat exchangers. Effectiveness as a function of the Number of Transfer Units and heat capacity ratio. Overall heat transfer coefficient, Fouling factor. Applications and selection of heat exchangers.	**06**
7	**Mass Transfer:** Mechanism of mass transfer. Importance of mass transfer in engineering. Fick's law of diffusion. Empirical relations for mass transfer regarding Sherwood Number, Reynolds Number and Schmidt's number.	**05**

Text Books:

1. Holman, J. P. "Heat transfer, Eighth SI Metric Edition." (2001)
2. Incropera and Dwitt, *Fundamentals of Heat and Mass Transfer,* Wiley India (2010)
3. Kreith, Frank, Raj M. Manglik, and Mark S. Bohn. *Principles of heat transfer* Cengage learning, (2012)
4. Arora C. P. ,*Heat and Mass Transfer*., Dhanpatrai and Co. (2014)
5. Nag P.K.,*Heat and Mass Transfer* , Tata McGraw Hill (2014)
6. Ozisik M.N., *Heat Transfer*, McGraw Hill (2010)
7. Rajput, R. K. "„Heat and Mass Transfer‟, pub." *Tata McGrawhill*(2009).

References:

1) Heat Transfer - Schaums Series - Mc Graw Hill International.
2) Welty, James R. "Engineering heat transfer." *New York, John Wiley and Sons, Inc.*(1974).
3) Hsü, Shao-ti. *Engineering heat transfer*. Van Nostrand, 1963.
4) Eckert and Drake, *Heat and Mass Transfer*, (2010)

PC-BTM502 Design of Machine Elements

Course pre-requisites: Mechanics

Course Objectives:

The primary objective of this course is

- To analyze the stress and strain on mechanical components and understand, identify and quantify failure modes for mechanical parts
- To define the detailed design procedure of simple machine elements as well as to apply the effect of different loading on it.
- To understand the detailed design procedure of the different types of joints and the effect of theories of failure on it.
- To understand the analysis of shafts and the effect of theories of failure.

Course Outcomes:

Upon successful completion of the course, students should be able

1. To formulate and analyze stresses and strains in machine elements subjected to static and fluctuating load conditions
2. To design and evaluate adequacy of standard/custom-built machine elements such as shafts, belts, chains, bolted/welded joints and springs to fulfil desired specifications and satisfy failure criteria
3. To examine and identify role of material selection, manufacturing requirements, aesthetic and ergonomic needs in design of machine elements
4. To demonstrate ability to plan and prescribe design of simple machine elements through engineering drawing and calculation report.

Course Content:

Module	Details	Hrs.
01	Mechanical Engineering Design, Design methods, Aesthetic and Ergonomics consideration in design, Design Standards, I.S. codes, Preferred Series and numbers. Material properties and their uses in design, Manufacturing considerations in design: tolerances, types of fits, selection of fits, Design considerations of casting and forging. Theories of failures, Factors of safety, Design Reliability	04
02	Design against static Loads: Cotter joint, knuckle joint. Power Screw– Design of Screw Presses.	04
03	Fatigue (Cyclic Load): Design against Fluctuating Loads, Variable stresses: reversed, repeated, fluctuating stresses. Fatigue Failure- Static and fatigue stress concentration factors, Endurance limit- estimation of endurance limit. Design for finite and infinite life- Soderberg and Goodman design criteria, Fatigue design under combined stresses. Creep considerations: Creep Curve	06
04	Design of shaft- power transmitting, power distribution, shafts (excluding crank shaft) under static and fatigue criteria. Keys–Types of Keys and their selection based on shafting condition. Couplings–Classification of coupling. Selection of Standard Bush Pin coupling.	08
05	Design of springs- Helical compression, tension springs under static and variable loads	06

	Construction and design considerations of Leaf springs	
06	Belt and Chain Drives: Design of Belts –Flat and V belt with Pulley construction, timing belts and pulleys, Selection of flat and V belts from manufacturer's catalogue, Introduction to Roller chain, Selection of Standard Roller chains.	06
07	Bolted and Riveted Joints – eccentrically loaded bolted and riveted joints Welded Joints – Design of single transverse, double transverse parallel fillet, eccentrically Loaded welded joint	08

Course Activities:
Term work shall comprise of

1. Exercises on the above topics in the form of design calculations with sketches and or drawings.
2. At least four A2 size drawing sheets shall be submitted.
3. MCQ based on topics mentioned in latest GATE syllabus

Text Books:

1. Bhandari, V. B. *Design of machine elements*. Tata McGraw-Hill Education, 2010.
2. Shigley, Joseph E., Charles R. Mischke, and Richard G. Budynas. *Mechanical engineering design*. McGraw-Hill,, 2004.
3. Robert, L. Norton. "Machine Design An Integrated Approach." (2006).

Recommended Data Books

1. V. Bhandari, *Machine Design Data Book*, McGraw Hill Education (2017)
2. Mahadevan K., Reddy K.B. *Design Data Handbook for Mechanical Engineering in SI and Metric Units*, CBS (2013)

Reference Books:

1. Spottes, M.F.,Terry E. S., and Lee E.H. *Design of machine elements*. Vol. 2. Pearson Education India, 2004.
2. Deutschman, D., Michels, W.J. and Wilson, C.E., Machine Design Theory and Practice, Macmillan, 1992.
3. Juvinal, R.C., Fundamentals of Machine Component Design, John Wiley, 1994.

PC-BTM503 CAD/CAM/CIM

Course Prerequisites: Engineering Drawing, Manufacturing Science

Course Objectives

The general objectives of the course are to enable the students to

- Understand the basic analytical fundamentals that are used to create and manipulate geometric models in computer programs.
- To visualize how the components look like before its manufacturing or fabrication
- To learn 2D & 3D transformations of the basic entities like line, circle, ellipse etc
- To understand the different geometric modeling techniques like solid modeling, surface modeling, feature based modeling etc.
- To understand the different types of curves like Bezier curve, B-Spline curve & Graphics Standards
- To understand different Algorithms for optimization of drawing of basic entities
- To understand NC, CNC and DNC technology and Concepts of compute integrated manufacturing (CIM)

Course Outcomes

At the end of the course

1. Students will be able to **explain** the theory in CAD/CAM/CIM
2. Students will be able to **formulate** APT & CNC programs as per the geometry of work piece
3. Students will be able to **solve** analytical problems on Geometrical Transformations, Algorithms, Bezier & B-Spline Curves.
4. Students will be able to **formulate** the programs on Geometrical Transformation Algorithms, Bezier & B-Spline Curves using IT tools like C/C++/MATLAB etc.

Course Contents:

Module	Details	28Hrs.
01	**INTRODUCTION & ELEMENTS OF INTERACTIVE COMPUTER GRAPHICS** The Design process, Concurrent engineering in Product design & development, CAD System Architecture. Two dimensional computer graphics, vector generation, the windowing transformation, three dimensional Computer graphics, viewing transformation, Line, Circle & Ellipse Algorithm, Visual realism, Hidden line removal & hidden surface removal algorithm, Shading Algorithm.	**05**

02	**TECHNIQUES FOR GEOMETRIC MODELING:** Graphic standards, Bezier curves, Cubic Spline curve, B-Spline curve, Jupiter Technology, Constructive solid geometry (CSG), Boundary Representation (B-Rep), Wire Frame Modeling, Solid Modeling, Surface Modeling, Parametric Modeling, Feature based modeling, AI, ML, DL & GENAI in 3D modeling, Feature recognition & introduction to Geometric feature extraction using ML & DL algorithms	**05**
03	**GROUP TECHNOLOGY, CAPP, and CAQC** Introduction to GT, Part Families, parts Classification & Coding, GT Machine cells, Benefits of GT. Introduction to Computer Aided Process Planning (CAPP), Retrieval type Process Planning Systems, Generative type Process Planning Systems, Benefits of CAPP, Artificial Intelligence & ML applications in CAPP & CAQC, PFA, Similarity coefficient matrix. Introduction to Computer Aided Quality Control (CAQC), Computers in QC, Computer Vision systems ,Contact Inspection methods, Non Contact Inspection methods, Computer Aided Testing.	**05**
04	**NC, CNC & DNC TECHNOLOGY:** Introduction to NC,CNC & DNC systems along with its advantages & disadvantages, Computer Aided Part Programming, Adaptive Control, Adaptive machining, CNC programming concepts, CNC, AIML in CNC, Constructional details of CNC machines, Feedback devices- Velocity & displacement, Flexible Manufacturing System (FMS), Rapid Prototyping	**06**
05	**TRANSFORMATION, MAINPULATION & DATA STORAGE** 2D & 3D Transformations, Concatenations, Matrix representation, Problems & Object Oriented Programming on Transformations. Data Structures for interactive modeling, Engineering Data Management System (EDMS), Relational Data Base for Design, Object Oriented Database, Structured Query Language (SQL), SQL Vs NOSQL, Design information Systems.	**06**
06	**COMPUTER INTEGRATED MANUFACTURING** Introduction, Evolution, Objectives, CIM Hardware and Software, CIM Benefits, Nature and role of the elements of CIM, Identifying CIM needs, Data base requirements of CIM, Role of CAD/CAM in CIM, Obstacles to Computer Integrated Manufacturing, Concept of the future CIM systems, Socio -techno- economic aspects of CIM.	**02**

07	**EMERGING AREAS in CAD/CAM** Design for Assembly (DFA), Reverse Engineering and Data Capture techniques, AIML in Design & Manufacturing, Green Manufacturing, DT, Virtual Manufacturing(VR), Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR).	**03**

Internal Evaluation

Internal Evaluation shall consist of class assignments on each module along with other components

Text Books:

1. "CAD/CAM Computer Aided and Manufacturing" by Mikell P. Groover and Emory W. Zimmers, Jr., Eastern Economy Edition,PHI
2. "CAD/ CAM , Theory & Practice" by Ibrahim Zeid, R. Sivasubramanian, Tata McGraw Hill Publications
3. "Computer Graphics" by Donald Hearn and M. Pauline Baker, Eastern Economy Edition
4. "CAD/CAM Principles, Practice and Manufacturing Management" by Chris McMahon, Jimmie Browne, Pearson Education
5. "CAD/CAM/CIM" by P. Radhakrishan, S. Subramanyan, V. Raju, New Age International Publishers
6. "CAD/CAM Principles and Applications" by P.N. Rao, Tata McGraw Hill Publications
7. "Principle of Computer Graphics" by William .M. Neumann and Robert .F. Sproul, McGraw Hill Book Co. Singapore.
8. "Computer Graphics & Product Modeling for CAD/CAM" by S.S.Pande, NAROSA Publication
9. David L. Goetsch, Fundamental of CIM technology , Delmar publication
10. David Bedworth, Computer Integrated Design and Manufacturing, McGraw Hill.
11. "CNC Machines" by B.S. Pabla and M. Adithan, New Age International Publishers.
12. "Numerical Control and Computer Aided Manufacturing", T.K. Kundra, P.N. Rao, N.K. Tiwari, Tata McGraw Hill
13. "CNC Technology and Programming", Krar, S., and Gill, A., McGraw Hill publishers
14. "Flexible Manufacturing Systems" by H.K. Shivanand, M.M. Benal, V.Koti, New Age International Publishers
15. "Automation, Production Systems and Computer Integrated Manufacturing ", Groover M.P., Prentice-Hall of India Pvt. Ltd
16. "Mathematical Elements for Computer Graphics", Rogers D F I and Adams J A, McGraw-Hill.

REFERENCE BOOKS

1. "Computer Integrated Manufacturing Hand Book" by Eric Teicholz, Joel N. Orr, *McGraw Hill International Editions*

2. "Computer Integrated Manufacturing- An Introduction with Case Studies" by Paul G. Ranky, *Prentice Hall International*

PC-BTM504 Mechatronics and Automation

Course Pre-requisites: Applied Mathematics, Basic electronics

Course Objectives:

The objective of the course is to focus on designing, analyzing, and implementing intelligent systems that integrate mechanical components with sensors, actuators, and microcontrollers.

Course Outcomes:

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

1. To explain principles of operation of microprocessor, microcontrollers, PLCs, in mechatronics systems
2. To use hydraulic and pneumatic actuation systems for developing circuits for industrial automation
3. To explain concepts of Stability
4. To explain state space representation of control systems

Course Content:

Module	Details	Hrs.
01	Introduction to Mechatronics, Mechatronics Systems in Factory, Home and Business Applications. Basic Components of Mechatronic Systems, Mechatronics Design process, Objectives	04
02	Overview of microprocessors and micro-controllers 8051microcontrollers: Functional block diagram and architecture, Instruction set and assembly language programming.	04
03	Pneumatic and Hydraulic actuation systems: Pneumatic and hydraulic systems. Electro-Pneumatic systems. Electro-Hydraulic systems. Development of circuits for Industrial Automation PLC in Automation: Basic structure, I/O processing. Ladder logic diagram. Selection of PLC.	04
04	Proportional, Integral, Derivative, Proportional Plus Integral plus Derivative controls, examples from mechanical and electrical systems.	04
05	Stability analysis: Introduction to concepts of stability, The Routh and Hurwitz Stability criteria, Relative stability analysis.	04
06	Root locus concepts. Frequency Response Analysis: Frequency domain specifications, Correlation between time and frequency response, Bode Plots.	04
07	State-Space methods, Single degree of freedom, Multi-degree of freedom, Forced response, State Space representation of Control systems. MATLAB programming for control system	04

Text books:

1. De Silva, C. W. (Year). Introduction to Mechatronics: An Integrated Approach. Springer, ISBN: 978-3-031-29320-7

2. Gaonkar, R. S. (1996). Microprocessor Architecture, Programming, and Applications with the 8085, Penram International Publishing. ISBN: 0070223635.
3. Ayala, K. J. (2000). The 80251 Microcontroller. Prentice Hall. ISBN: 855232055.
4. Goyal, S. C., and Bakshi, U. A. Control Systems Engineering. Technical Publications, 2010.
5. FESTO Text book on Pneumatic Circuits

References:

1. Horowitz, Paul, and W. Hill. "Art of electronics 2nd edn.".
2. Fundamentals of Pneumatics: Festo Series
3. Fundamentals of Electro-Pneumatics: Festo Series
4. Fundamentals of Hydraulics: Festo Series
5. Fundamentals of Electro-Hydraulics: Festo Series
6. Mechatronics, H. M. T. "Tata McGraw Hill." New Delhi.
7. Pippenger, John J. Hydraulic valves and controls: selection and application. Marcel Dekker Inc,
8. Dukkipati, Rao V. Analysis and design of control systems using MATLAB. New Age International, 2006.

Other Resources:

1. NPTEL Course: Mechatronics, By Prof. Pushparaj Mani Pathak, IIT Roorkee

Sr. No.	Examination	Module
1	**T-I**	1, 2
2	**T-II**	3, 4
3	**IA**	1 to 7
4	**End Sem**	1 to 7

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	1								2	2	
CO2	3	3	3	3	3								2	2	
CO3	3	3	3	3	3								2	2	1
CO4	3	3	3	3	3	2	2				2	2	2	2	1

PC-BTM551 Heat and Mass Transfer Laboratory

Course Pre-requisites: Thermodynamics, Fluid Mechanics and Engineering Mathematics

Course Objectives:

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

1. Identify different modes of heat and mass transfer occurring in thermal systems,
2. Analyze steady and transient conduction problems,
3. Learn the fundamentals of convective heat transfer,
4. Understand and analyze the radiative mode of heat transfer,
5. Understand the methods of analyzing a heat exchanger,
6. Learn about the basic concept of mass transfer

Course Outcomes:

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

1. Understand different modes of heat transfer and estimate the total heat transfer
2. Understand design concepts of different heat exchanger equipment
3. Analyze heat exchange through different modes of heat transfer
4. Develop equations for different modes of heat transfer

The list of Experiments to be conducted is as follows.

Term work shall consist of a minimum of **06** experiments and at least one assignment on each module.

1. To find the Thermal conductivity and Thermal resistance of composite material.
2. To find the emissivity of a given radiating surface.
3. To study the working and construction of Heat pipes.
4. To study heat transfer by Natural convection.
5. To study heat transfer by Forced convection.
6. To study heat transfer from Pin-Fin

Term Work:

The term work will comprise of following

1. Journal of laboratory experiments.
2. At least one assignment on each module of the theory course.
3. Examination (MCQ) based on topics mentioned in latest GATE syllabus
4. Oral Examination
5. Mini Presentation on small topic of the syllabus

PC-BTM553 CAD/CAM/CIM Laboratory

Course pre-requisites: Engineering Graphics

Course Objective:

In this course, students will:

1. Learn to understand drawing, which includes clear spatial visualization of objects and proficiency in reading and interpreting a wide variety of production drawings.
2. Learn drafting skills depending upon job function to perform day-to-day activities, i.e. communicating and discussing ideas with supervisors and passing instructions to subordinates. also, knowledge of computer-aided drafting is an essential part.

Course Outcome:

Upon successful completion of this course, students should be able:

1. To create and compose engineering drawings for standard machine components on CAD Software.
2. To sketch free hand proportionate illustrative representation of common machine components.
3. To assemble various standard machine components on CAD Software.
4. To plot assembly and detail production drawings with bill of Material.

Course Contents:

Practical Work based on modules of PC-BTM515 course:

List of Practical's / Lab work

1. Creating 3D Solid model
2. Creating Assembly Model
3. Creating Surface Model
4. Creating Parametric Model
5. Program for Brenham's Algorithms for Line
6. Program for Brenham's Circle Algorithms
7. Programs for 2D Transformations
8. Programs for 3D Transformations
9. Program for Bezier & B-Spline Curves

During practical work, students should be introduced to CAD software features related to collaborative drawing (attach or reference another drawing within a part/assembly drawing), insertion of standard parts using blocks, history-based or feature modelling, parametric modelling, dimensional and geometric constraints.

PC–BTM554 Mechatronics and Automation Laboratory

Course Pre-requisites:

Course Objectives:

- In the recent trend of automation in industry environment has changed very fast from mechanical to electromechanical. Hence aim is to implement such a mechatronics system in industry to enhance the performance as well as cost, size & power. Such as microcontroller base systems & programmable logic controller base systems.
- Knowledge of systems such as microprocessor, microcontroller, Programable logic controller, Electropneumatic & electro hydraulics & other systems such as MATLAB & software's will be useful.

Course Outcomes:

Upon successful completion of the course, students should be able

1. To do interfacing of microprocessor, microcontrollers, PLCs, in mechatronics systems
2. To do programming for Mechatronics system
3. To use hydraulic and pneumatic actuation systems for developing circuits for industrial automation
4. To simulate of control systems using IT tools

Course Contents

The list of Experiments to be conducted is as follows.

1. Study of Microprocessor 8051 and experiments.
2. Study of Electro-pneumatic Logic Trainer kit and experiments on Electro-pneumatic circuits
3. Study of PLC and experiments on PLC.
4. Experiments on Control System using MATLAB
5. Experiments on mathematical models using SIMULINK
6. Experiments using Fluid SIM.

Term Work:

The term work will comprise of following

1. Journal of laboratory experiments.
2. At least one assignment on each module of the theory course.
3. Examination (MCQ)
4. Oral Examination
5. Mini project

PE-BTM511 Finite Element Methods

Course pre-requisites: Strength of Materials, Engineering Mathematics

Course Objectives:

1. To explain the finite element method, its fundamentals, and general steps.
2. To understand the underlying theory, assumptions and modelling issues in FEM.
3. To study the formulation of elemental characteristics matrices.
4. To provide hands on experience using finite element software to model, analyze and design mechanical engineering systems.

Course Learning Outcomes:

After successful completion of the course, the student should be able to

1. Formulate a numerical model for a given system.
2. Obtain solutions for given problems.
3. Solve mechanical engineering problems using FEA techniques.
4. Carry out FE analysis using commercial software.

Course Content:

Module	Details	Hrs.
01	Introduction to FEM- DOF, elements, nodes and interpolation. Brief History. Applications of FEM in various fields. Advantages and disadvantages of FEM. FEA procedure.	3
02	Types of Differential Equations used in various engineering fields, Primary and Secondary Variables and types of Boundary Conditions. Matrix Algebra Matrix operations, Gauss Elimination Method to get inverse of a Matrix.	3
03	Formulation Techniques: Galerkin and other Weighted Residual Methods	6
04	Formulation Techniques: Variational Methods, Reyleigh-Ritz Method	6
05	One dimensional Elements and computational procedures. Bar and Beam element. Stiffness Matrix, Assembly of Stiffness matrix. Loads-mechanical and thermal (temperature DOF). Boundary Conditions.	8
06	Two dimensional elements and computational procedure. Interpolation and shape functions. Three nodded triangular element, four nodded rectangular element, four nodded quadrilateral element, and Isoparametric elements, Numerical Integration and Gauss quadrature, solution to the problem.	8
07	Introduction to 3D Elements	4

Course Project

In course projects, students shall integrate and apply the knowledge gained during the fundamental courses of Mechanical Engineering. The projects will be developed by teams of a maximum of two students (using any analysis software) and shall consist of problem definition, model preparation, appropriate selection of elements,

mesh generation, post-processing, simulation and validation of results.

Course Activities:

- Term work shall consist of a minimum **03** assignments (one on each module)
- Hands-on practice on finite element software for 1D and 2D problems.
- Hand on the practice of NASA-NASTRAN software for solving FEA problems

Text Books:

1) P. Seshu. *Textbook of Finite Element Analysis*, Prentice Hall, 2003
2) Logan, *Finite Element Method*, CL Engineering, Fifth Edition, 2010.
3) Reddy J. N. *Finite Element Method*, McGraw Hill Education, Third Edition, 2005

References:

1) R.D. Cook. *Concepts & Applications of Finite Element Analysis*.
2) Bathe, K.J., *Finite Element Procedures in Engineering Analysis*, Prentice Hall of India.
3) C.S. Krishnamoorthy. *Finite Elements Analysis*, Tata McGraw Hill
4) S.S. Rao. *The Finite Element Method in Engineering*, 4th Edition, Academic Press, Elsevier
5) Desai and Abel. *Introduction to Finite Elements Methods,* CBS Publication.

Sr. No.	Examination	Module
1	T-I	1,2
2	T-II	3,4
3	End Sem	1 to 7

PE-BTM512 Lean and Green Manufacturing

Course pre-requisites: Manufacturing Sciences

Course Objectives-

- To introduce the concepts and practices of Lean and Green
- To make the students aware of Lean and Green assessment tools.
- To enable the students to apply the Lean and Green concepts in various fields.

Course Outcomes-

1. Students will learn the basic concepts of Lean manufacturing
2. Students will be able to explore the waste in organizations as per the Lean principles
3. Students will be able to develop the New Process using the VSM
4. Students will learn the basics of green manufacturing and identify the best practices used in the manufacturing environment

Course Contents:

Module	Description	Hrs.
01	**Introduction to Lean and Green Manufacturing** Evolution of Lean; Objectives of Lean and Green Manufacturing; key principles; Implications of lean and Green Manufacturing, Concept of Lean; Toyota's foray in Lean;	06
02	**Lean System Design - Value Stream Management** Definition of Value and value stream; Definition of waste - 3 Ms Muda, Mura, Muri - 7 Types of Muda; Value Stream Mapping (VSM) Types; TAKT Time	06
03	**Tools/Techniques/Methodologies/Practices for Lean System Implementation** **(A)Flow Stage:** Work place organization (5S principles); Concept of Kaizen/ continuous improvement; Single Minute Exchange of Die Pokayoke; Prevention & Detection Types; Maintenance - Preventive, Time Based and Condition Based; total productive maintenance; Autonomous Maintenance; Poke Yoke; Process Stability – Losses, 7 Major Losses Reduction-Overall Equipment Effectiveness (OEE) **(B) Pull stage:** **Just In Time Manufacturing (JIT):** Introduction - elements of JIT - uniform production rate - pull versus push method- Kanban system: Types of Kanbans and Practical Application, case studies;	06
04	**Lean and Green Metrics and Assessment** Identify Lean and Green Metrics; Steps involved in Goal Setting; Corporate Goals; Lean Assessment- Framework/Models of Lean and Green assessment, Global Prizes/Awards for sustainable lean and Green implementation.	06
05	**Lean Sustenance** Human Development for sustainable Lean implementation; Involvement of Employees, Cultural Change; Reviews; Recognition; Improving Targets and Benchmarking the best practices; Road map.	06

06	**Applications of Lean and Green in Different Sectors** Lean and Green New Product Development, Lean Software Development – CMMI Level 4 (Quality Improvement) and Level 5 (Quality Optimization), Lean and Green Construction, Lean Healthcare, Lean in Education system etc. A case study on application of Lean in any sector.	06
07	**Reconciling Lean with Other Systems** Lean and Green Manufacturing, Barriers for Green manufacturing , Green Supplier Development, Critical success Factors for Green Manufacturing Value Stream Mapping, Waste Identification	06

Term Work:
Assignments based on the above topics.
Case study Preparation [Minimum 2 case studies]

Reference Books:

1. Micheal Wader, "Lean Tools: A Pocket Guide to Implementing Lean Practices", Productivity and Quality Publishing Pvt Ltd, 2002.
2. Taiichi Ohno, Toyota, "Production System Beyond Large-Scale production", Productivity Press (India) Pvt.Ltd., 1992.
3. Green Manufacturing: Fundamentals and Applications (Green Energy and Technology) 2012th Edition, by David A. Dornfeld (Editor), Springer Publications
4. Green Manufacturing Processes and Systems, by J. Paulo Davim (Editor), Springer Publications
5. Don Tapping, Tom Luyster and Tom Shuker, "Value Stream Management"
6. Tom Luyster, "Your Lean Future State"
7. Kenichi Sekine, "One-Piece Flow", Productivity Press, Portland, Oregon, 1992.
8. Mike Rother and Rick Harris, "Creating Continuous Flow"
9. Rick Harris, Chris Harris & Earl Wilson, "Making Materials Flow"
10. Askin R G and Goldberg J B, "Design and Analysis of Lean Production Systems", John Wiley and Sons Inc., 2003.
11. Alan Robinson, "Continuous Improvement in Operations", Productivity Press, Portland, Oregon, 1991.
12. Poke - Yoke, "Improving Product Quality by Preventing Defects", Productivity Press, 1992.

Sr. No.	Examination	Module
1	T-1	1 and 2
2	T-2	3 and 4
3	Final Examination	1 to 7

PE-BTM513 Introduction to Cryogenics

Course pre-requisites: Thermodynamics, Heat and Mass Transfer

Course Outcomes:

The objectives of this course are

1. To explain the history and developments, principles, scope and applications of Cryogenic Engineering as a science of generation, retention and distribution of extremely low temperatures.
2. To explain and illustrate fundamental concepts, properties and principles of behaviour of engineering materials and cryogenic fluids at cryogenic temperatures.
3. To explain and illustrate fundamental concepts and principles of cryogenic insulation, vacuum technology and safety aspects in Cryogenic Engineering.
4. To explain fundamental principles, detailed features of arrangements, operation of various cryogenic cycles for liquefaction of gases and illustrate its applications to evaluate and compare performance parameters of practical cryogenic cycles and liquefactions systems with critical components involved.

Course Outcomes:

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

1. To understand the history and developments, fundamental principles as well as scope and applications of Cryogenic Engineering.
2. To understand fundamental concepts, properties and principles of behavior of engineering materials and cryogenic fluids at cryogenic temperatures and apply them to practical cryogenic systems to evaluate and compare their performance parameters.
3. To understand fundamental concepts and principles of cryogenic insulations, vacuum technology and safety aspects and apply them to practical cryogenic systems to evaluate and compare their performance parameters.
4. To understand fundamental principles, detailed features of arrangements and operations of various cryogenic cycles for liquefaction of gases and apply them to practical cryogenic systems to analyze, evaluate and compare their performance parameters.

Course Contents:

Module No.	Details	Hrs.
1.	**Introduction to Cryogenic Engineering:** • Meaning and definition, Historical background • Progress of Cryogenic Engineering • Scope of Cryogenics and Role of Cryogenic Engineers • Present areas of applications involving Cryogenic Engineering, Principles of Thermodynamics, Heat Transfer, Momentum Transfer, Cooldown etc.	05
2.	**Low-Temperature Properties of Engineering Materials** **Properties of solids**: • Mechanical Properties, Thermal Properties, Electrical and Magnetic Properties of solids including metals and non-metals (insulators) • Design considerations, Material selection criterion for Cryogenic	06

	Applications **Properties of cryogenic fluids:** • Fluids other than Hydrogen and Helium • Hydrogen and Helium	
3.	**Gas Liquefaction Systems-I:** • Introduction, System performance parameters • The thermodynamically ideal system • Production of low temperatures: Joule-Thompson effect, Adiabatic expansion • Simple Linde-Hampson system, Precooled Linde- Hampson system, Linde dual pressure system, Cascade system, Claude system, Kapitza system, Heylandt system. Liquefaction systems for LNG Comparison of performance parameters of liquefaction systems	07
4.	**Gas Liquefaction Systems-II** **Liquefaction systems for Neon and Hydrogen:** • Pre-cooled Linde-Hampson system for Neon and Hydrogen, Claude system for Neon and Hydrogen, Helium refrigerated Hydrogen liquefaction system, Ortho-Para Hydrogen conversion **Liquefaction systems for Helium:** • Collins's system, Simon's system **Critical components of liquefaction systems:** • Heat Exchangers, Compressors and expanders Effect of Losses for real machines and heat transfer to system on its performance	07
5.	**Cryogenic Insulations:** • Introduction, Heat transfer, Concept of apparent thermal conductivity • Different types of cryogenic insulations: Expanded foam insulations, Gas-filled powders and fibrous insulations, Vacuum insulation, Evacuated powder and fibrous insulations, Opacified-powder insulations, Multilayer insulations • Composite insulation, Adhesives and other materials, Placement of insulation.	06
6.	**Vacuum Technology:** • Importance of vacuum technology in cryogenic engineering,Flow regimes in vacuum systems • Components of vacuum system • Different types of vacuum pumps: Mechanical vacuum pumps, Diffusion pumps, Ion pumps, Cryopumping, Getters and sorption pumping, Vacuum gauges	06
7.	**Safety Aspects with Cryogenic Systems:** • Introduction, General safety principles, Safety checklist, Physiological hazards, Suitability of materials and construction techniques • Explosions and flammability, Excessive pressure gas • **Special considerations for Hydrogen and Oxygen gas**	05

Term work:

1. At least one assignment on each module comprising theoretical concepts and numerical examples.

2. Technical / Case study presentations on course contents applicable to Cryogenic industry/ Plants/ R & D Institution.
3. Participation in activities such as industry expert lecture/ industry visit etc. organized by faculty for providing the wider exposure to students.
4. At least one MCQ Test based on course contents of GATE Examination.

Assessment: Attendance :5 Marks, Assignment Work:10 Marks, Viva-voce/ MCQTest 10 Marks.

Term Activity with Industry 4.0 Approach

1. Industry visit to Cryogenic plant/ industry / R & Organization of repute.
2. Lectures/seminar by experts from Cryogenic plant/ industry / R & D organization.
3. Internship (of one to two weeks) in a Cryogenic plant/ industry / R & D organization.
4. Case study: Recent developments viz: Gas liquefaction, insulation, vacuum technology etc. from Cryogenic Industry/ Plants/ R & D Institution of repute.

Text Book:

1. Barron, Randall F., *Cryogenic Systems*, 2nd edn,, Oxford University Press, New York, 1985.

Reference Book:

1. Flynn, Thomas M., *Cryogenic Engineering*, 2nd edn, CRC Press, New York, 2005.

Recommended NPTEL/ Online Lectures / Courses

1. Cryogenic Engineering NPTEL Course Lectures by Prof. M.D. Atrey, IIT Bombay
https://nptel.ac.in/courses/112/101/112101004/

PE-BTM 514 Compressible Fluid Flow

Course Co-requisites: Fluid Mechanics

Course Objectives:

The objective of the course is to make students familiar with the basic behaviour of compressible fluids so that they can use this understanding to acquire deeper knowledge in the applied domain (high-speed flow) and solve simple real-life problems.

Course Outcomes:

Upon completion of this course, students should be able to:

1. To define the fundamental principles of compressible flows and related terminology, and identify the case of a compressible flow.
2. To describe and explain the basic principles and related mathematical models.
3. To apply the knowledge, perform calculations and solve simple real-life problems.
4. To analyse and design a given system and recommend a better solution after its evaluation.

Course Contents:

Module	Description	Hrs.
1	**Fundamental Concepts:** Concept of compressibility- Ideal gas, speed of sound, Mach number, Governing equations: mass, momentum, energy and entropy equations; Illustrations of few applications where compressible flow study is applicable.	04
2	**One Dimensional Isentropic Flow Through Variable Area**: Isentropic relations; One-D compressible adiabatic duct flow, critical properties; Converging nozzles, choking, converging-diverging nozzles, rocket nozzles;	06
3	**Flow Through Normal Shocks**: Development of shock wave, Governing equations, Prandtle Meyer relation, Property changes across shocks, Tables and charts for normal shock waves	06
4	**Flow Through Oblique Shocks**: Nature of flow, Fundamental relations, Rankine- Hugoniot Equation, Variation of flow parameters, Gas table for oblique shocks;	06
5	**One Dimensional Duct Flow with Heat Transfer** Rayleigh flow and equations, *T-s* diagrams, choked Rayleigh flow;	08
6	**One Dimensional Duct Flow with Friction** Fanno Flow Equation, Choked Fanno Flow, Comparison and Summary of 1-D flows;	06
7	**Wind Tunnel:** Fundamentals of wind tunnels, types of wind tunnels, Design of wind tunnels. Application in compressible flow study;	06

TERM WORK:

Term work shall consist of class assignments on each module.

Recommended Books:

1. Fox and McDonald, "*Introduction to Fluid Mechanics*", John Wiley & Sons, 8ed.
2. Frank M. White, "*Fluid Mechanics*", McGraw Hill, 7ed.
3. John David Anderson, "Modern compressible flow: With historical perspective", McGraw Hill
4. S M Yahya, "Fundamentals of compressible flow", New Age Publication
5. V Babu, "Fundamental of gas dynamics, Wiley
6. Shapiro A H, "The Dynamics And Thermodynamics Of Compressible Fluid Flow", Ronald Press

PE-BTM 515 Nature Inspired Design and Innovation

Course Co-requisites: Material Science, Applied Physics, Applied Chemistry, Design

Course Objectives: The objective of this course is to:

1. Provide learning from nature
2. Provide exposure to various designs available in nature,
3. Provide understanding, working and construction features of designs found in nature,
4. Learn about innovations derived from nature

Course Outcomes:

Upon completion of this course, students should be able to:

1. To describe the needs of various designs available in nature for specific purpose,
2. To investigate possibility to mimic the designs inspired from nature,
3. To analyze the innovations inspired from nature
4. To correlate the appropriate design for specific needs

Course Content:

Module	Descriptions	Hrs.
1	**Introduction:** Early Attempts at Biomimicry: The Influence of Birds on the Development of Aircraft. The Fathers of Modern Biomimetics: Percy Shaw and George de Mestral	4
2	**Transport, Motion, and Energy** Birds and Bullet Trains Owl-Inspired Noise Reduction, Humpback Whales and Wind Turbines A Tree-Inspired Wind Turbine Fuel Efficiency Inspired by Sharks	6
3	**Colour and Light:** Photonic Biomimicry Photonic Cooling Biomimetic Antireflective Coatings A Novel Glass Inspired by Spiders	4
4	**The Built Environment** Cooling Buildings the Termite Way Functional Structures Inspired by Nature Self-Cleaning Surfaces Self-Healing Concrete New Building Materials	6
5	**Smart Materials** Self-Cleaning Materials Novel Adhesives Novel Glues Inspired by Marine Animals Glues from Terrestrial Slugs	6

	Gecko-Inspired Dry Adhesives A Polar Bear-Inspired Material for Heat Insulation Novel Textiles	
6	**Smart Devices** Bioinspired Underwater Pressure Sensors Crack-Based Strain Sensors Passive Water Collection Collecting Water with Spiders' Webs Insects and Origami Mosquito Bites and Injection Needles	6
7	**The Influence of Biology on Computer Science** Genetic Algorithms Swarm Intelligence Human Swarming **The Future Trends in Nature Inspired Design and Innovations**	4

Internal Evaluation (IE)

The consolidated submission for IE will comprise of following

1. At least one assignment on each module of the theory course.
2. Oral Examination
3. Case study on Nature Inspired Design and Innovation
4. Synthesis of any design found in nature.

Recommended Books:

1. Biomimetics: Nature-Inspired Design and Innovation -Sandy B. Primrose, Wiley Blackwell, 2020.
2. Yoseph Bar-Cohen, Biomimetics: Nature-Based Innovation, CRC Press, 2016
3. Ashok K G, Daniel A McAdams, Robert B. Stone, Biologically inspired designs: computational methods and tools, Springer London, 2013.
4. Lakhtakia A, Martin-Palma RJ (eds); Engineered biomimicry; Elsevier, 2013
5. Reich Y, A critical review of General Design Theory. Research in Engineering Design, 7 (1) 1-18 (1995).
6. Maria G. Trotta, Bio-inspired Design Methodology, International Journal of Information Science 1(1), pp 1-11 (2011).

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	1	1	2					1	2	2	
CO2	3	3	3	3	3	2	2					1	2	2	
CO3	3	3	3	3	3	2	2					1	2	2	
CO4	3	3	3	3	3	2	2				2	2	2	2	

MI-BT022 Minor-2

The course content of all Minors offered by the institute during an academic year is provided separately. Students are advised to visit the list of Minors to see the details of the associated courses and their course contents.

PC-BTM601 Refrigeration and Air conditioning

Course pre-requisites: Thermodynamics, Fluid Mechanics, Thermal Systems, Heat and Mass Transfer

Course Objectives:

- Understand the fundamentals involved in basic refrigeration and air-conditioning.
- Understand the principle of working and construction of air conditioners, refrigerators and other related equipment.
- Learn about current issues of ODP, TEWI and the effects of air-conditioning on global warming.
- Learn about properties of air, summer and winter air conditioning and its heat load estimation with issues related to human comfort.

Course Outcomes:

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

1. Explain the basic refrigeration cycles like vapor compression cycle, vapour absorption cycle, aircraft refrigeration cycles, cascade refrigeration and properties of air.
2. Evaluate the performance of devices working on vapor compression cycle and the vapour absorption cycle.
3. Outline properties of refrigerants, environment friendly refrigerants, properties of air and human comfort.
4. Estimate the cooling / heating load for an air conditioning systems.

Course Content:

Module	Details	Hrs.
01	Introduction to Refrigeration, Carnot's refrigerator, a unit of refrigeration, Coefficient of Performance, Energy Efficiency Ratio, Simple Vapour Compression Refrigeration Cycle, Effect of liquid sub-cooling and suction vapour super heating, Use of liquid-vapour Heat Exchanger (LVHE). Actual VCR cycle.	10
02	Applications and Components • Overview of Applications like household refrigerators, Window and Split air conditioners, Air conditioning of Multi-storied buildings, Green Buildings, and Aircraft Refrigeration • Desirable properties of refrigerants, Thermodynamic, Chemical and Physical properties, Designation system for refrigerants. ODP, GWP, TEWI, Secondary refrigerants Types of Compressors, Condensers, Evaporators, Expansion devices, Controls – Safety Controls and Operating Controls	06
03	**Vapour Absorption Refrigeration System**: Ammonia Water, Water/Lithium Bromide system-Single Effect, Double Effect Electrolux refrigeration system, Introduction to Adsorption Refrigeration system	06

04	**Psychrometry:** Psychrometric properties, chart and processes, Bypass factor, ADP, Adiabatic mixing of two air streams, RSHF , RADP, CADP, GSHF, ESHF, Cooling Towers, Types, Approach, Range, Efficiency, Components and maintenance.	06
05	**Cooling Load Estimation**: Cooling Load estimation, Design of summer and winter air-conditioning systems.	06
06	**Air Distribution Systems**: Friction chart for circular ducts, Equivalent diameter of a circular duct for rectangular ducts, Static pressure regain and equal friction drop methods of duct design, AHU and its components.	06
07	**Human Comfort**: Effective temperature, Comfort chart, Comfort zone, Methods of improving Indoor Air Quality (IAQ), Recent trends in IAQ.	02

Text Books

1. Arora, Chandra Prakash. *Refrigeration and air conditioning*. Tata McGraw-Hill Education, 2000.
2.Dossat, R. J., and Thomas J. Horan. *Principles of refrigeration*, 2002.
3.Stoecker, W. F., and J. W. Jones. *Refrigeration and air conditioning*, Mc GrawHill Book Co, New York, 1982.

References Books

1.Ananthanarayanan, P. N. *Basic refrigeration and air conditioning*. Tata McGraw-Hill Education, 2013.
2.Handbook, A. S. H. R. A. E. "Fundamentals." *American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta* 111 (2001).
3.Handbook, Shan K. Wang, "Handbook of Air Conditioning and Refrigeration", Mc Graw Hill Book Co., New York, 2000.

Mapping of CO of the course PC-BTM611 with POs/PSOs

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO1	3		-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	2	2	2	-	-	-	-	-	-	-	-	-	-	-
CO3	3		-	-	-	2	2	-	-	-	-	-	-	-	-
CO4		2	2	2	-	-	-	-	-	-	-	-	-	-	-

PC-BTM602 Thermal and Fluid Machines

Pre-requisite Courses: Thermodynamics, Fluid Mechanics

Course Objective:

To understand the fundamental concepts, constructional features and applications of various thermal and fluid machinery.

Course Outcome:

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

1. Understand the fundamentals of different thermal and fluid machinery
2. Apply knowledge of thermodynamics and fluid mechanics to study the performance of different thermal and fluid machinery.
3. Analyse, compare and select different thermal and fluid machinery for an application.
4. Evaluate performance of various thermal and fluid machinery.

Course Content:

Module	Details	Hrs.
01	**Compressors** Single and multistage reciprocating compressor. Calculation of minimum work, Free air delivered, volumetric efficiency, isothermal and adiabatic efficiency. Roto-dynamic compressor- rotary, axial and centrifugal. Performance characteristics of compressors.	8
02	**Pumps** Classifications- Reciprocating, Centrifugal and Axial flow, Performance characteristics, Series and parallel arrangements.	6
03	**Internal Combustion Engines: Spark Ignition (SI)** Theory of Carburetion, Simple carburetor, various systems of actual Carburetor, Ignition System - Battery and Magnetic Ignition, Electronic Ignition. Combustion phenomenon, knocking, Ignition delay, Petrol Injection -MPFI etc.	8
04	**Internal Combustion Engines: Compression Ignition (CI)** Requirement of fuel injection systems and types of fuel injection, Fuel injection pump, types of nozzles. Necessity of Governor in diesel engines. Combustion phenomenon, Stages of combustion, Delay period, Applications	6
05	**Steam Generators and Steam Turbines:** High-pressure steam generator. Constructional and working features, accessories- superheaters, economizers, reheaters, air preheaters. Once through steam generator, control of steam generation. Examples of HP boilers, Flow through the steam nozzle, Basic of steam turbine, Classification, compounding of the turbine, Impulse turbine-velocity diagram, condition for maximum efficiency. Reaction turbine- velocity diagram, degree of reaction, Parson's turbine. Condition for maximum efficiency.	8
06	**Gas Turbine**: Constructional features, Applications, Open and closed cycle gas turbine, methods to improve efficiency and specific output, Effect of operating variable on thermal efficiency and work ratio.	6
07	**Hydraulic Turbines** Classification, Impulse turbine – Pelton wheel, Reaction turbines- Francis and Kaplan, Performance characteristics.	6

Text Books:

1. Nag, P. K. *Power plant engineering*. Tata McGraw-Hill Education, (Latest edition)..
2. Kothandaraman, C. P., S. Domkundwar, and Anand Domkundwar. *Cource in Thermal Engineering*. Dhanpat Rai & Company (P) Limited, (Latest edition).
3. Yadav, R. "Steam and gas turbine and Power Plant Engineering." (Latest edition).
4. Yahya, S. M. *Turbines compressors and fans*. Tata McGraw-Hill Education, (Latest edition).
5. Lal, Jagdish. *Hydraulic machines*. Metropolitan Book Company, latest ed..
6. Sharma, R. P., and M. L. Mathur. "*Internal Combustion Engine."* Dhanpat Rai & Company (P) Limited, (Latest edition) .
7. Obert, Edward F. "*Internal combustion engines and air pollution."* Intex Educational Pub (Latest edition).
8. Ganesan, V. *Internal combustion engines*. McGraw Hill Education (India) Pvt Ltd,.

References:

1. Sorensen, Harry A. *Principles of Thermodynamics*. Holt, Rinehart and Winston,
2. Eastop, T. D., and A. McConkey. "Applied thermodynamics for engineering technologists,
3. Yunus A Cengel and Michael A. Boles, *Thermodynamics an Engineering Approach*. Tata McGraw-Hill Education.

PC-BTM603 Manufacturing Planning and Control

Course pre-requisites:

Course Objectives:

Basically, this course consists of two streams Production Management and Operation Research.

- After learning this Course, the student will understand the Basic concepts, Principles of Production Management and Operation Research
- The student will learn the various Tools and Techniques like Forecasting techniques, Project Network Analysis Techniques, Production scheduling Techniques in detail and will be position to use them suitably.
- The student will also learn some Case studies of materials management, Purchase Management to reinforce their concepts.

Course Outcomes:

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

1. Describe the Basic concepts, Principles of Production Management and Operation Research
2. Apply the various Tools and Techniques like Forecasting techniques
3. Analyse Project Network and to learn and apply Production scheduling Techniques
4. Examine Cases of materials management, Purchase Management to reinforce their concepts

Course Content:

Module No.	MODULE	HRS
01	**Manufacturing Planning and Control System:** Need to Learn Manufacturing Planning and Control, Manufacturing transformation process, Manufacturing as competitive advantage. Manufacturing system –components and types. MPC system overview objectives and functions such as planning routing, scheduling, dispatching and follow up.	6
02	**Forecasting:** Need for forecasting, Types of forecast. Extrapolative methods- Moving average method, Exponential smoothing method, Forecast errors, Linear trend model. Causal methods- Simple regression analysis. AI models of Forecasting **Capacity Planning:** Need of capacity planning decisions, Aggregate Capacity Planning, Capacity variation Strategies	
03	**Planning for Material requirements:** Material Requirement Planning, Master Production Schedule, Inventory control systems, Economic Order Quantity. Buffer stocks. Purchase and Production type of inventory. Quantity discount. Concept of JIT. Toyota Production System, Demand Driven MRP	6
04	**Scheduling & Sequencing**: Scheduling concept, Scheduling of processes, Gantt chart, Job shop scheduling, - Comparison of various methods, Sequencing of tasks using, Johnson's rule.	8
05	**Project Management**: Concepts of project, planning, monitoring and control,	6

	Project management through network analysis, CPM & PERT	
06	**Advanced Concepts In Production Planning I:** Mathematical programming approaches- Linear programming problem, Formulation, Simplex method for maximization and minimization, Concept of duality, Assignment model, Transportation model.	4
07	**Advanced Concepts In Production Planning II**: **Simulation:** Need for simulation, Monte Carlo technique, Use of Crystal-Ball Software **Simple Queuing Model** • Characteristics of Queueing Systems • Queueing Notation – Kendall Notation • Long-run Measures of Performance of Queueing Systems **Replacement Model,** • Replacement of items that deteriorate with time • Replacement of Items that do not deteriorate but fail after a certain amount of use • Money Value, Present worth Factor and discount Rate group Replacement Policy **Network Flow Models (Petri Nets)** • Introduction to Petri Nets and their types • Petrinet properties • Modeling with Petri Nets	6

Term Work:

- The Term work shall comprise at least seven assignments (Problems and Case Studies) covering different topics of the syllabus.
- Examination (MCQ) based on topics mentioned in the latest GATE syllabus

Text Book:

1. Thomas E..Vollmann, William L.. Berry, and D. Clay Whybark.*Manufacturing planning and control systems*. Irwin/McGraw-Hill, 1997.
2. Chary, S. N. *Production and operations management*. Tata McGraw-Hill, 1988.
3. Jhamb L.C., *Modernization of Materials Management,* Everest Publishing House, 1999.
4. Taha, Hamdy A. *Operations Research: An Introduction (For VTU)*. Pearson Education India, 1982.

Reference Books:

1. Buffa E.S., Sarin R.K., *Modern production / Operations management*, Wiley, 1987
2. Telsang, Martand. *Industrial engineering and production management*. S. Chand, 2006.
3. Bewoor A., *Manufacturing Process Planning and System Engineering*, Dream-tech Press, 2009
4. Sharma J.K., *Operation Research*, Macmillan, 2009.
5. Narasimhan, Seetharama L. *Production planning and inventory control*. Pearson College Division, 1995.
6. Wayne W., *Operation Research*, Cengage Learning, 1987
7. Shah R., Soni H., *Operation Research*PHI Learning, 2009

8. Panneerselvam, R. *Research methodology*. PHI Learning Pvt. Ltd., 2014.
9. Ebert R.J., Adams E.E., *Production Operation Research*, PHI Learning, 1986.

PC-BTM651 Refrigeration and Air Conditioning Laboratory

Course Co-requisite: Thermodynamics

Course Objectives: The students after studying these topics should be able to

- Understand fundamentals involved in refrigeration and air-conditioning
- Understand construction and principle of working of compressors, air conditioners, and refrigerators.
- Learn about current issues of ODP, TEWI and effects of air-conditioning on global warming.
- Learn about air-conditioning processes.

Course Outcomes:

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

1. Know the working of refrigerators, air-conditioners and other equipment's used in HVAC.
2. Know working of various devices used in refrigerators and air conditioners.
3. Know use of refrigerants and importance of human comfort.
4. Calculate COP of refrigerators, heat pumps and air-conditioners.

Course Contents:

Experiments:

1) Experiments to find COP for equipment's like Split air conditioner, domestic refrigerator
2) Experiments on Air and water Heat Pump, Benchtop Cooling Tower
3) Experiments involving the study of humidification dehumidification, heating and cooling, Adiabatic Mixing of two air streams.
4) Visit report- Cold storage plant / ice plant or air-conditioning site visit.

Term Work:

The term work will comprise of following

1. Journal of laboratory experiments.
2. At least one assignment on each module of the theory course.
3. Oral Examination
4. MCQ based on topics mentioned in latest GATE syllabus

PC–BTM652 Thermal and Fluid Machine Laboratory

Course Co-requisites: Thermal and Fluid Machines

Course Objective:

The students after studying these topics should be able to

- Understand working of compressors.
- Understand working of nozzles and steam turbines.
- Get knowledge about working of steam generators
- Understand performance parameters and working of gas turbines.

Course Outcome:

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

1. To know effect of parameter like delivery pressure on the volumetric efficiency of reciprocating air compressor
2. To understand effect of inlet pressure and back pressure on mass flow rate through C-D Nozzle
3. Get working knowledge of centrifugal pumps, IC Engines-SI &CI
4. To understand torque speed and power speed characteristics of gas reaction turbine.

Course Contents

List of experiments to be performed.

1. Trial on air compressors.
2. Trial on experimental gas turbine
3. Experiment on mass flow rate of air through orifice plate or nozzle.
4. Study of steam turbines.
5. To perform performance test on a centrifugal pimp
6. To perform load test on Pelton and Francis Turbine
7. To perform load test on Petrol Engines.
8. To perform load test on Diesel Engines

Term Work:

The term work will comprise of following

1. Journal of laboratory experiments.
2. At least one assignment on each module of the theory course.
3. Examination (MCQ) based on topics mentioned in latest GATE syllabus

PE-BTM611 Computational Fluid Dynamics

Course Co-requisites: Fluid Mechanics

Course Objectives:

To equip students with the fundamental concept of computational fluid dynamics and provide training for basic features of the heat and flow analysis software.

Course Outcomes:

On successful completion of the course students will be able to

1. To identify the need of modelling and simulation and understand its execution methodology.
2. To define, analyse and interpret a case of thermo-fluid problem.
3. To examine, illustrate and compare the results of different cases under changed boundary conditions.
4. To formulate a problem for its complete CFD analysis.

Course Contents:

Module	Description	Hrs.
1	**CFD Fundamentals:** Modeling and Simulation Computational Fluid Dynamics - its Scope, Application, advantages and disadvantages. Overall methodology of CFD analysis -Preprocessing, Solver, Post processing	04
2	**Mathematical Description of Physical Phenomenon:** Concept of mathematical modeling, Basic conservation equation In differential and Integral form, General thermal and flow boundary condition, Mathematical nature of partial differential equation used in thermo-fluid analysis.	06
3	**Numerical Solution of Linear Algebraic Equation:** Direct Method – Matrix inversion, Gauss Elimination, LU decomposition. Iterative Method- Features of iterative techniques, Jacobi and Gauss Seidel Method, Relaxation method (SUR and SOR). Stability and convergence, Ill-conditioned system of equation and condition number,	06
4	**Numerical Modeling of Heat Conduction:** Steady One and two dimensional Conduction, Unsteady One and two Dimensional Conduction, Stability restrictions,	06
5	**Numerical Modeling of Convection-Diffusion:** Numerical treatment of convective terms- FOU, SOU, QUICK, Power law scheme. Steady One-dimensional and Two Dimensional Convection- Diffusion, Unsteady One-dimensional Convection-Diffusion, Unsteady Two-dimensional Convection-Diffusion	08
6	**Incompressible Fluid Flow:** Governing Equations, Complexities in solving flow problems,	06

	Determination of Pressure for Viscous Flow, SIMPLE, SIMPLER and PISO Algorithm	
7	**Turbulence Modeling:** Introduction to Turbulence Modeling, Basic Theories of Turbulence Reynolds Time-Averaged Equations for Turbulent Flow, Different turbulence models.	06

Activities: Minimum **<u>06 (Six)</u>** assignments/tutorials

Recommended Books:

1. Versteeg H.K. and Malalasekera.W: " An introduction to computational fluid dynamics-The finite volume method", Prentice Hall
2. Anderson, D.A., Tannehill, I.I., and Pletcher, R.H., "Computational Fluid Mechanics and Heat Transfer", Hemishphere Publishing Corporation,.
3. Subas, V.Patankar, "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation
4. Muralidhar, K. and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House.
5. Ghoshdasdidar, P.S.,"Computer Simulation of flow and heat transfer" Tata McGraw-Hill Publishing Company Ltd.

a. Niyogi.P. Laha M.K., Chakrabarty S.K.: "Introduction to Computational Fluid Dynamics". Pearson Education, India.

6. Fletcher, C.A.J."Computational Techniques for Fluid Dynamics 1" Fundamental and General Techniques, Springer-Verlag

PE-BTM612 Composite Materials

Course pre-requisites: Manufacturing Science, Material Science

Course Objectives:

The objective of this course is to:

- Explain types of composite materials and their applications
- Describe manufacturing processes for composite materials
- Discuss mechanical properties of composites

Course Outcomes:

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

1. Characterization of composite materials and identify its applications to mechanical engineering systems
2. Synthesis of different types of composites
3. Selection of manufacturing processes for composite materials
4. Investigation of mechanical properties of composites

Course contents:

Module	Description	Hrs.
1	**Overview of composite materials** Historical background, Classification based on structure and matrix, Advantages and limitations, industry applications,	06
2	**Composite materials** Reinforcement fibers, whiskers, polymer matrix composites (PMC), Metal matrix composites (MMC), Ceramic matrix composites (CMC),	06
3	**Composite Science** Material and microstructure parameters of layered and phased composites, micro and macro approaches to study and prediction of structure property relations.	06
4	**Introduction to micromechanics** Anisotropy of composites, anisotropic elastic constants, failure criteria under multiaxial loading, interlaminar failure mechanism	06
5	**Composite manufacturing processes** Manufacturing of reinforcement fibers and whiskers, preparation of fillers, additives and pigments for PMC, manufacturing of matrix polymers, manufacture of metallic matrices, processing of ceramics, manufacture of foams, honeycombs and adhesives.	06
6	**Composite post processing operation** Machining, cutting, polishing, welding of thermoplastic PMC, bonding, riveting and painting	06
7	**Composite product design** ASTM standards for composites, Material considerations in composite product design, material design of thermal, optical, acoustic, electrical design requirements, design exercise for design of simple structural element such as tension bar and ring, Repair of Composites, Embedded sensors. Introduction to Nano Composites	06

	ANSYS or ABACUS software for the modelling and analysis of composite material, Case studies on application of the composites	

Internal Activities:

It consists of **at least one** tutorial and/or assignments and/or hands-on exercises from each module of the curriculum mentioned for the course.

Reference Material:

1. K.K. Chawla, Composite Materials – Science & Engineering, Springer-Verlag, New York, 1987.
2. Analysis and Performance of Fiber Composites, Bhagwan D. Agarwal, Lawrence J. Broutman, K. Chandrashekhara, Wiley, 2006
3. Handbook of Composites, George Lubin, Van Nostrand, Reinhold Co., 1982

PE-BTM613 Tool Engineering

Course pre-requisites: Manufacturing Sciences

Course Objectives:

The objective of this course is to:

- As a result of having learned this module 1, the students will be able to understand mechanics metal cutting, different factors influencing machining phenomenon, Tool life, Economic consideration for process adoption.
- As a result of having learned this module 2, students will be able to analyze the requirements of tool design for an case and design cutting tools like single point cutting tool, drill, milling cutter etc.
- As a result of having learned this module 3, the students will be able to understand the concept of measurement of forces in machining in different operations. They will also understand the criteria for selection of the cutting fluid.
- As a result of having learned this module 4, the students will be able to get introduced and develop the knowledge and skills for rolling and forming operations.
- As a result of having learned this module 5, the students will understand fundamental of forging process, its mechanism and die design principles.
- As a result of having learned this module 6, the students will develop the knowledge and skills to design press tools for blanking, piercing and non-cutting operations.
- As a result of having learned this module 7, the students will be able to introduce and develop the knowledge related to forming of sheet metal.

Course Outcomes:

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

1. To explain metal cutting principles and important analytical aspects of machining process.
2. To select and design Cutting tools for various machining processes and specify the effects of machining environment on machining mechanism.
3. To explain mechanism of operation for rolling, forging of metal and significance of design of rolling and forging dies.
4. To understand effect and use of different sheet metal forming and working processes for different applications.

Course contents:

Module	Description	Hrs.
1	**Metal cutting fundamentals:** Mechanics of machining –geometry of cutting tools, chip formation, cutting forces and power requirements, wear and tool life, Economics of Metal Cutting parameters affecting machining cost, Tool life for minimum cost max productivity	06

2	**Design of cutting Tools:** Design of cutting Tools Types of tools, Tool geometry, Tool signature, Design of single point cutting tool, Design of Drill, Reamer, Broach, Milling Cutter	06
3	**Characterization of cutting process:** Measurement of cutting Forces, Types of tool dynamometers, Coolants types of coolants, choice of coolants, Effects of coolants on various cutting parameters, cutting fluids, machine-ability	06
4	**Rolling of metals:** Principles of rolling, Characteristic of rolling, Rolling mills and their types, Rolling parameters, Principles of roll pass design, Calculation of design parameters for rolls Forging, Extrusion, Rotary Swaging Processes, types, advantages, limitations and applications.	06
5	**Forging of metals:** Classification of forging processes, open-die forging & spread law, closed die-forging & die design, forging equipments, weight calculation of initial material in forging, forging defects Die Design for drop Forging and press Forging	06
6	**Sheet metal working:** Operations, Introduction of sheet metal working, Press, Classification of presses, Selection of presses, Difference between Hydraulic and Mechanical Press, Types of Cutting operations and non cutting operation, Different elements of die set assembly, Design of dies like simple die, progressive die, compound die, combination die, Bending die, Drawing die, Forming die	06
7	**Sheet metal forming:** Introduction and Classification of Metal Forming Processes, Advantages and Limitations, Stress strain relations in elastic and plastic deformation, concept of flow stresses, deformation mechanisms, Hot and Cold Working Processes and its effect on Mechanical Properties. **Principle, process parameters, equipment's and application of the following processes:** spinning, stretch forming, plate, V and edge bending, Curling, Ironing, Roll Bending, Metal Spinning. Press brake forming, explosive forming, Hydro forming, electro hydraulic forming, and magnetic pulse forming. High Velocity forming of metals and High energy Rate forming.	06

Recommended Books:

1. 1.S. Kalpakjian & S.R. Schmid, "Manufacturing Engineering and Technology, fourth edition", PEARSON
2. G. Boothroyd & W.A. Knight, " Fundamental of Machining and Machine Tools, third edition", CRC.
3. Milton C. Shaw, "Metal Cutting Principles", OXFORD University Press
4. O.P. Khanna, "A Textbook of Production Technology", Dhanpat Rai Publications
5. Cyril Donaldson, George H. LeCain , Tool Design, TATA McGraw Hill,2012

6. W A J Chapman ,Workshop Technology Part 1,2,&3 , Edward Arnold, 01-Jan-1972
7. B. L. Juneja&Sekhon, Fundamentals of Metal Cutting and Machine Tools, New Age Intl.
8. V.D. Kodgire, “Material Science and Metallurgy”, Everest Publishing House - 25 th. Edition – 2009.
9. HMT Banglore, Tata McGraw-Hill Education, 2001
10. Hajra Choudhary, S.K. and Hajra Choudhary A.K. ,Elements of Workshop Technology, Vol. II, Media Promoters, Mumbai. Shaw, M.C. (2005)
11. Jain R.K. & Gupta S.C."Production Technology " : Khanna Publisher, New Delhi, ; 8th Edition

Practical work:

1. Experiments on given set-up for different tool material, workpiece, cutting conditions, chip morphology study, tool geometry.
2. Industrial visit report (format should be provided by teacher)
3. Seminar presentation on the topic related to any one of the topics.

PE-BTM614 Mechanical Vibration

Course pre-requisites: Dynamics of Machinery

COURSE OBJECTIVES

1. To develop skill to model a mechanical system as a single or multi-degree of freedom vibration problem.
2. To provide knowledge of analytical and experimental methods of vibration analysis

COURSE OUTCOMES

The student should be able to –

1. Model a physical system using various principles.
2. Estimate response for the given system.
3. Evaluate response for the given system.
4. Justify parameters required for vibration control.

Course Content

Module no.	Description	hrs
1	SDOF Systems – Arbitrary Excitation Single degree of freedom systems-harmonic excitation – An Overview.	**03**
2	Forced single degree of freedom vibration system Analysis of linear and torsional systems subjected to harmonic force and harmonic motion excitation (excluding elastic damper). Force and motion Transmissibility.	06
3	MDOF Systems – Free and Forced Vibrations Multi degree of freedom systems, Free, damped and forced vibrations of two degree of freedom systems, Eigen values and Eigen vectors, normal modes and their properties, mode summation method.	**06**
4	Vibrations of Continuous Systems : Introduction to vibrations of strings, bars, shafts and beams; Mode shapes and natural frequencies.	**06**
5	Numerical and computer methods in vibrations: Rayleigh, Rayleigh-Ritz and Holzer's method etc.	**06**
6	Equivalent single degree of freedom Vibration system. Conversion of multi –springs, multi masses, multi dampers into a single spring mass and damper with linear or rotational co-ordinate system, vibration isolation	**06**
7	Vibration measuring instruments Principle of seismic instruments, Vibrometer, accelerometer, sensors used in measurement. Introduction to FFT analyzer and fault analysis, Vibration sensors and IoT	**06**

Term work:

Assignment containing numerical problems and case-studies based on above topics

Text Books

1. G. K. Grover, Mechanical Vibrations, Nem Chand & Bros, Eighth Edition, 2009
2. Graham Kelly, Fundamentals of Mechanical Vibration, Tata McGraw Hill, 2000
3. P.L. Ballaney, Theory of Machines, Khanna Publishers, Delhi.
4. Rao S. S., Mechanical Vibrations, Pearson, 2018.

FP-BTM601 Field Project

Course pre-requisites: All fundamental courses of the mechanical engineering

Course Objective:

The objective of the field project is to integrate theory with practices in society or industries. Students will be able to understand and work on real-world challenges and issues. It can be used to learn, investigate, analyze, and conclude to develop a solution to a problem, which may be a local technical, social problem or industrial problem. The field project may be extended to a major project with the additional scope of the problem. It can be a group work.

Course Outcomes:

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

1. integrate the knowledge of the fundamentals of subjects to search the related literature and devise solutions,
2. use knowledge for formulation/fabrication of the desired project,
3. analyze the available resources and select the most appropriate one,
4. apply principles of ethics and standards, skill of presentation and communication techniques.

Course content:

Sr.no.	Description	Hrs./week
1	Students should visit industries and social institutes/organizations and understand their systems. They can pick up a live problem, if any, or identify an existing system that can be analyzed for a better technical solution. If it is a group project, the work must be distributed among the group members. The work may involve- data collection, analysis, and inferencing. The student shall prepare an interim report and shall present a seminar on the work done at the end of the semester.	2

MI- BT023 Minor-3

The course content of all Minors offered by the institute during an academic year is provided separately. Students are advised to visit the list of Minors to see the details of the associated courses and their course contents.