Course code	Course Name	L-T-P	Credits	Year of Introduction
IE306	SUPPLY CHAIN AND LOGISTICS MANAGEMENT	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To develop knowledge on structures, decision phases, measures and tools of supply chains.
- To develop understanding on the strategic, tactical and operational decision tools of supply chains.
- To impart knowledge on logistics management and related advanced tools and techniques.

Syllabus

General features of supply chains, planning demand and supply, forecasting, aggregate planning, network design, locations, layouts etc. Supply chain inventory planning decisions, multi-echelon cycle and safety inventory systems: Logistics management: design of transportation network. Routing, scheduling and sequencing. Advanced logistics decision models.

Expected Outcome

The students will

i. Understand the structures, decision phases, measures and tools of supply chains.
ii. Understand the strategic, tactical and operational decision tools of supply chains.
iii. Understand knowledge on logistics management and related advanced tools and techniques.

Text Books

1. G. Sreenivasan, Quantitative Models in Operations and Supply Chain Management, PHI
2. Sunil Chopra, Peter Meindl, Supply Chain Management – Strategy, Planning and Operation, Pearson Education.

References

1. David Simchi – Levi & Philip Kaminsk, Designing and Managing the Supply Chain, McGraw-Hill Companies Inc.
2. David Taylor and David Brunt, Manufacturing Operations and Supply Chain Management, Vikas Thomson Learning, 2001.
3. Donald J. Bowersox & David J. Closs, Logistical Management, TMH.
4. Jeremy F. Shapiro, Modeling and Supply Chain,. Thomson Learning, 2001.
5. Martin Christopher, Logistics and supply chain management, Financial times management.

COURSE PLAN

Module	Contents	Hours	End-Sem. Exam. Marks
I	**General Features of Supply Chains:** Supply Chains – Structures, Decision Phases, Performance Drivers and Measures, Metrics. Achieving Strategic Fit and its Obstacles.	7	15%

II	**Planning Demand & Supply:** Planning demand and supply in supply chains – Forecasting techniques for supply chains, Seasonal Forecasting Models, Measure of Forecast errors.	**7**	**15%**
FIRST INTERNAL EXAM			
III	**Aggregate Planning:** Aggregate Planning Strategies, Aggregate Planning models - Quantitative Examples. **Network Design, Locations and Layouts:** Network design in Uncertain Environment, Facility Location and Layout decisions.	**7**	**15%**
IV	**Multi-echelon Inventory Systems:** Inventory Planning Decisions –Estimate of Cycle Inventory, Discounting Models, Multi-item Inventory models, Determination of Safety Inventory, Impact of Supply Uncertainty, Multi- echelon Inventory models, Quantitative Examples. Bullwhip effect.	**7**	**15%**
SECOND INTERNAL			
V	**Logistics Management**: 3PL, 4PL, Design Options for Transportation Network. Routing, Scheduling and Sequencing in Transportation, Vehicle Routing Problems. Quantitative Examples.	**7**	**20%**
VI	**Reverse Logistics:** Reverse logistics and Closed Loop Supply Chains. **Advanced Logistics Decision Models:** Bin Packing Problems, Fixed Charge Problems, Knapsack Problems, Multi-stage transportation problems.	**7**	**20%**
END SEMESTER EXAM			

End Semester Examination Question Paper Pattern

Examination duration: 3 hours Maximum Marks: 100

Part A (Modules I and II):
Candidates have to answer any 2 questions from a choice of 3 questions. Each full question carries a total of 15 marks and can have a maximum of 4 sub questions (a, b, c, d). No two questions shall be exclusively from a single module. All three questions shall preferably have components from both modules. Marks for each question/sub question shall be clearly specified. Total percentage of marks for the two modules put together as specified in the curriculum shall be adhered to for all combinations of any two questions.

Part B (Modules III and IV):
(Same as for part A marks)

Part C (Modules V and VI):
(Same as for part A, except that each full question carries 20 marks)

Note: If use of tables and charts are permitted for the university examination for this course, proper direction of the same should be provided on the facing sheet of the question paper.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME401	DESIGN OF MACHINE ELEMENTS - I	3-1-0-4	2016

Prerequisite: ME201 Mechanics of Solids

Course Objectives:

- To review concepts of statics and strength of materials.
- To introduce fundamental approaches to failure prevention of components.
- To provide knowledge in the design of common machine elements such as fasteners, shafts, springs cotter joints and couplings.

Syllabus

Introduction to Design, Materials and their properties, Theories of Failure, Shock and impact loads,Threaded Joints, Bolted joints, Design of riveted joints, Cotter and Knuckle joints, Design of welded joints, Helical springs, Leaf springs, Shafting, Design of Coupling.

Expected outcome:

The students will be able to

i. Find out various stresses induced in a machine element under different type of loading conditions.
ii. Devise machine components for its conceptual design.

Text Books:

1. Jalaludeen , Machine Design, Anuradha Publications, Chennai,2014
2. R. L. Norton, Machine Design – An Integrated Approach, Pearson Education, 2001
3. V.B.Bhandari, Design of Machine elements, McGraw Hill, 2010

Data books permitted for reference in the final examination:

1. K. Mahadevan, K.Balaveera Reddy, Design Data Hand Book, CBS Publishers & Distributors, 2013
2. NarayanaIyengar B.R & Lingaiah K, Machine Design Data Handbook, Tata McGraw Hill/Suma Publications, 1984
3. PSG Design Data, DPV Printers, Coimbatore, 2012

References Books:

1. J. E. Shigley, Mechanical Engineering Design, McGraw Hill,2003
2. Juvinall R.C & Marshek K.M., Fundamentals of Machine Component Design, John Wiley,2003
3. M. F. Spotts, T. E. Shoup, Design of Machine Elements, Pearson Education, 2006
4. Rajendra Karwa, Machine Design, Laxmi Publications,2006

Course Plan			
Module	**Contents**	**Hours**	**End Sem. Exam Marks**
I	Introduction to Design- Definition, steps in design process, preferred numbers, standards and codes in design	4	15%
	Materials and their properties- Elastic and plastic behaviour of metals, ductile and brittle behaviour, shear, bending and torsional stresses, combined stresses, stress concentration factor.	5	
II	Theories of Failure- Guest's Theory, Rankine's Theory, St. Venant's Theory, Haigh's Theory, and Von Mises and Hencky Theory.	5	15%
	Shock and impact loads, fatigue loading, endurance limit stress, factors affecting endurance limit, factor of safety	6	
FIRST INTERNAL EXAM			
III	Threaded Joints- Terminology, thread standards, types of threads, stresses in screw threads	3	15%
	Bolted joints- effect of initial tension, eccentric loading, design of bolts for static and fatigue loading, gasketed joints, power screws	4	
IV	Design of riveted joints- Material for rivets, modes of failure, efficiency of joint, design of boiler and tank joints, structural joints	4	15%
	Cotter and Knuckle joints- Gib and Cotter Joint, analysis of knuckle joint.	4	
	Design of welded joints- welding symbols, stresses in fillet and butt welds, Butt joint in tension, fillet weld in tension, fillet joint under torsion, fillet wed under bending, eccentrically loaded welds.	4	
SECOND INTERNAL EXAM			
V	Springs- classification, spring materials, stresses and deflection of helical springs, axial loading, curvature effect, resilience, static and fatigue loading, surging, critical frequency, concentric springs, end construction.	5	20%
	Leaf springs- Flat springs, semi elliptical laminated leaf springs, design of leaf springs, nipping	4	
VI	Shafting- material, design considerations, causes of failure in shafts, design based on strength, rigidity and critical speed, design for static and fatigue loads, repeated loading, reversed bending	5	20%
	Design of Coupling- selection, classification, rigid and flexible coupling, design of keys and pins	3	
END SEMESTER EXAM			

Question paper pattern

Use of approved data book permitted

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 3 questions from module I and II and at least 1 question from each module
Each question carries 15 marks
Students will have to answer any 2 questions out of 3 (2X15 marks =30 marks)

Part B
There should be 3 questions from module III and IV and at least 1 question from each module
Each question carries 15 marks
Students will have to answer any 2 questions out of 3 (2X15 marks =30 marks)

Part C
There should be 3 questions from module V and VI and at least 1 question from each module
Each question carries 20 marks
Students will have to answer any 2 questions out of 3 (2X20 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME403	ADVANCED ENERGY ENGINEERING	3-0-0-3	2016

Prerequisite: Nil

Course Objectives:

1. To give an idea about global energy scenario and conventional energy sources
2. To understand solar, wind and Biomass energy
3. To know concepts of other renewable energy sources
4. To create awareness on the impacts of energy conversion and importance of sustainable energy

Syllabus

Global and Indian energy scenario, conventional energy sources, environmental effect of energy conversion, renewable energy sources- solar, wind, biomass, brief account of other renewable energy sources –geothermal, tidal, MHD, hydrogen, fuel cells, small scale hydro power plants. Environmental impact and Sustainability issues.

Expected outcome:

The students will be able to

i. Understand energy scenario and the environmental effects of energy conversion.
ii. Become aware of different renewable energy sources and choose sustainable energy for future

Text Books:

1. Jefferson W Tester et.al., Sustainable Energy: Choosing Among Options, PHI, 2006
2. P K Nag, Power Plant Engineering, TMH, 2002
3. Tiwari G N, Ghosal M K, Fundamentals of renewable energy sources, Alpha Science International Ltd., 2007

References Books:

1. David Merick, Richard Marshall, Energy, Present and Future Options, Vol.I & II, John Wiley & Sons, 2001
2. Godfrey Boyle, Renewable Energy : Power for a Sustainable Future, Oxford University Press, 2012
3. Roland Wengenmayr, Thomas Buhrke, 'Renewable Energy: Sustainable energy concepts for the future, Wiley – VCH, 2012
4. Twidell J W and Weir A D, Renewable Energy Resources, UK, E&F.N. Spon Ltd., 2006

Course Plan

Module	Contents	Hours	End Sem. Exam Marks
I	Introduction to the course. Global and Indian energy resources. Energy Demand and supply. Components, layout and working principles of steam, hydro, nuclear, gas turbine and diesel power plants	7	15%
II	Solar Energy- passive and active solar thermal energy, solar collectors, solar thermal electric systems, solar photovoltaic systems. Economics of solar power. Sustainability attributes.	7	15%
FIRST INTERNAL EXAM			

III	Wind Energy-Principle of wind energy conversion system, wind data and energy estimation, wind turbines, aerodynamics of wind turbines, wind power economics. Introduction to solar-wind hybrid energy systems	7	15%
IV	Biomass Energy – Biomass as a fuel, thermo-chemical, bio-chemical and agro-chemical conversion of biomass- pyrolysis, gasification, combustion and fermentation, transesterification, economics of biomass power generation, future prospects.	6	15%
SECOND INTERNAL EXAM			
V	Other Renewable Energy sources – Brief account of Geothermal, Tidal , Wave, MHD power generation, Small, mini and micro hydro power plants. Fuel cells – general description, types, applications. Hydrogen energy conversion systems, hybrid systems- Economics and technical feasibility	8	20%
VI	Environmental impact of energy conversion – ozone layer depletion, global warming, greenhouse effect, loss of biodiversity, eutrophication, acid rain, air and water pollution, land degradation, thermal pollution, Sustainable energy, promising technologies, development pathways	7	20%
END SEMESTER EXAM			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME 405	REFRIGERATION AND AIR CONDITIONING	2-1-0-3	2016

Prerequisite: ME205 Thermodynamics

Course Objectives:

1. To introduce vapour compression and vapour adsorption systems
2. To impart knowledge on refrigeration cycles and methods to improve performance
3. To familiarize the components of refrigeration systems
4. To introduce air conditioning systems
5. To know the applications of refrigeration and air conditioning systems

Syllabus

Introduction, Thermodynamics of refrigeration, Air refrigeration systems, Vortex tube refrigeration, Adiabatic demagnetization of paramagnetic salts, Vapour compression systems, Refrigerants and their properties, Application of refrigeration, Refrigeration system components, Air conditioning, Psychrometry, Air conditioning systems.

Expected outcome:

The students will be able to

i. Understand the principles refrigeration of air-conditioning and basic design considerations.
ii. Carry out analysis of refrigeration cycles
iii. Apply the concepts of indoor environmental comfort.
iv. Perform psychrometric calculations, humidity control and analysis of air-conditioning processes
v. Know the various applications of Refrigeration and air conditioning

Text Books:

1. Arora C. P, Refrigeration and Air-Conditioning, McGraw-Hill, 2008
2. Arora S. C. and Domkundwar, Refrigeration and Air-Conditioning, Dhanpat Rai, 2010
3. Ballaney P. L, Refrigeration and Air-Conditioning, Khanna Publishers, New Delhi, 2014
4. Manohar Prasad, Refrigeration and Air-Conditioning, New Age International, 2011

References Books:

1. ASHRAE Handbook
2. Dossat. R. J, Principles of Refrigeration, Pearson Education India, 2002
3. Stoecker W.F, Refrigeration and Air-Conditioning, McGraw-Hill Publishing Company, 2009

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Introduction – Brief history and applications of refrigeration. Thermodynamics of refrigeration- reversed Carnot cycle- heat pump and refrigeration machines, Limitations of reversed Carnot cycle. Unit of refrigeration- Air refrigeration systems- Reversed Joule cycle, Air craft refrigeration systems, simple bootstrap- Regenerative and reduced ambient system	6	15%

II	Vortex tube refrigeration-Very low temperature refrigeration systems (concept only). Adiabatic demagnetization of paramagnetic salts Vapour compression systems-simple cycle - representation on T- s and P- h Diagrams. COP- Effect of operating parameters on COP – methods of improving COP of simple cycle- super- heating , under cooling, Liquid suction heat exchanger, actual cycle.	8	15%
FIRST INTERNAL EXAM			
III	Multi pressure systems - multi compression and multi evaporator, systems. Inter cooling - flash inter cooling and flash gas removal- Different combinations of evaporator and compressor for different applications, Cascade system Refrigerants and their properties-Eco-friendly Refrigerants, mixed refrigerants, selection of refrigerants for different applications Vapour absorption systems - Ammonia – water system - simple system- drawbacks-Lithium Bromide water system- Electrolux- comparison with vapour compression system- steam jet refrigeration.	7	15%
IV	Application of refrigeration- domestic refrigerators- water coolers- ice plants. Cold storages- food preservation methods- plate freezing , quick-freezing. Refrigeration system components- Compressors, condensers, expansion devices, evaporators. Cooling towers- Different types and their application fields- Refrigerant leakage and detection – charging of refrigerant – system controls.	6	15%
SECOND INTERNAL EXAM			
V	Air conditioning – meaning and utility, comfort and industrial air conditioning. Psychometric properties- saturated and unsaturated air, dry, wet and dew point temperature – humidity, specific humidity, absolute humidity, relative humidity and degree of saturation- thermodynamic equations- enthalpy of moisture- adiabatic saturation process -psychrometers. Thermodynamic wet bulb temperature, psychometric chart- Psychometric processes- adiabatic mixing- sensible heating and cooling- humidifying and dehumidifying, air washer – bypass factor- sensible heat factor-RSHF and GSHF line- Design condition- Apparent dew point temperature – Choice of supply condition, state and mass rate of dehumidified air quantity – Fresh air supplied –air refrigeration. Comfort air conditioning- factors affecting human comfort. Effective temperature – comfort chart. Summer air conditioning- factors affecting-cooling load estimation.	8	20%
VI	Air conditioning systems- room air conditioner- split system- packaged system-all air system-chilled water system. Winter air conditioning – factors affecting heating system, humidifiers. Year round air conditioning AC system controls-thermostat and humidistat. Air distribution systems- duct system and design- Air conditioning of restaurants, hospitals, retail outlets, computer center, cinema theatre, and other place of amusement. Industrial applications of air conditioning.	7	20%
END SEMESTER EXAM			

Question Paper Pattern

Use of approved Refrigerant tables permitted

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME407	MECHATRONICS	3-0-0- 3	2016

Prerequisite: Nil

Course Objectives:

- To introduce the features of various sensors used in CNC machines and robots
- To study the fabrication and functioning of MEMS pressure and inertial sensors
- To enable development of hydraulic/pneumatic circuit and PLC programs for simple applications

Syllabus

Introduction to Mechatronics, sensors, Actuators, Micro Electro Mechanical Systems (MEMS), Mechatronics in Computer Numerical Control (CNC) machines, Mechatronics in Robotics-Electrical drives, Force and tactile sensors, Image processing techniques, Case studies of Mechatronics systems.

Expected outcome:

The students will be able to

i. Know the mechanical systems used in mechatronics
ii. Integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems

Text Books:

1. Bolton W., Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Person Education Limited, New Delhi, 2007
2. Ramachandran K. P., G. K. Vijayaraghavan, M. S. Balasundaram, Mechatronics: Integrated Mechanical Electronic Systems, Wiley India Pvt. Ltd., New Delhi, 2008.
3. Saeed B. Niku, Introduction to Robotics: Analysis, Systems, Applications, Person Education, Inc., New Delhi, 2006.

References Books:

1. David G. Aldatore, Michael B. Histand, Introduction to Mechatronics and Measurement Systems, McGraw-Hill Inc., USA, 2003.
2. Gordon M. Mair, Industrial Robotics, Prentice Hall International, UK, 1998.
3. HMT, Mechatronics, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2004.
4. Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, Smart Material Systems and MEMS: Design and Development Methodologies, John Wiley & Sons Ltd., England, 2006.

Course Plan

Module	Contents	Hours	End Sem. Exam Marks
I	Introduction to Mechatronics: Structure of Mechatronics system. Sensors - Characteristics -Temperature, flow, pressure sensors. Displacement, position and proximity sensing by magnetic, optical, ultrasonic, inductive, capacitive and eddy current methods. Encoders: incremental and absolute, gray coded encoder. Resolvers and synchros. Piezoelectric sensors. Acoustic Emission sensors. Principle and types of vibration sensors.	8	15%

II	Actuators: Hydraulic and Pneumatic actuators - Directional control valves, pressure control valves, process control valves. Rotary actuators. Development of simple hydraulic and pneumatic circuits using standard Symbols.	7	15%
FIRST INTERNAL EXAM			
III	Micro Electro Mechanical Systems (MEMS): Fabrication: Deposition, Lithography, Micromachining methods for MEMS, Deep Reactive Ion Etching (DRIE) and LIGA processes. Principle, fabrication and working of MEMS based pressure sensor, accelerometer and gyroscope.	6	15%
IV	Mechatronics in Computer Numerical Control (CNC) machines: Design of modern CNC machines - Mechatronics elements - Machine structure: guide ways, drives. Bearings: anti-friction bearings, hydrostatic bearing and hydrodynamic bearing. Re-circulating ball screws, pre-loading methods. Re-circulating roller screws. Typical elements of open and closed loop control systems. Adaptive controllers for machine tools. Programmable Logic Controllers (PLC) –Basic structure, input/ output processing. Programming: Timers, Internal Relays, Counters and Shift registers. Development of simple ladder programs for specific purposes.	8	15%
SECOND INTERNAL EXAM			
V	System modeling - Mathematical models and basic building blocks of general mechanical, electrical, fluid and thermal systems. Mechatronics in Robotics-Electrical drives: DC, AC, brushless, servo and stepper motors. Harmonic drive. Force and tactile sensors. Range finders: ultrasonic and light based range finders	6	20%
VI	Robotic vision system - Image acquisition: Vidicon, charge coupled device (CCD) and charge injection device (CID) cameras. Image processing techniques: histogram processing: sliding, stretching, equalization and thresholding. Case studies of Mechatronics systems: Automatic camera, bar code reader, pick and place robot, automatic car park barrier system, automobile engine management system.	7	20%
END SEMESTER EXAM			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A

There should be 2 questions each from module I and II. Each question carries 10 marks. Students will have to answer any three questions out of 4 (3X10 =30 marks)

Part B

There should be 2 questions each from module III and IV. Each question carries 10 marks. Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C

There should be 3 questions each from module V and VI. Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME409	COMPRESSIBLE FLUID FLOW	2-1-0-3	2016

Prerequisite: ME205 Thermodynamics

Course Objectives:

- To familiarize with behavior of compressible gas flow.
- To understand the difference between subsonic and supersonic flow
- To familiarize with high speed test facilities

Syllabus

Introduction to Compressible Flow, Wave propagation, One dimensional steady isentropic flow, Irreversible discontinuity in supersonic flow, Flow in a constant area duct with friction (Fanno Flow), Flow through constant area duct with heat transfer (Rayleigh Flow), Compressible flow field visualization and measurement, measurement in compressible flow, Wind tunnels

Expected outcome:

The students will be able to

i. Formulate and solve problems in one -dimensional steady compressible flow including: isentropic nozzle flow, constant area flow with friction (Fanno flow) and constant area flow with heat transfer (Rayliegh flow).
ii. Derive the conditions for the change in pressure, density and temperature for flow through a normal shock.
iii. Determine the strength of oblique shock waves on wedge shaped bodies and concave corners
iv. Know the various measuring instruments used in compressible flow

Data book/Gas tables:

1. Yahya S. M., Gas Tables**,** New Age International, 2011
2. Balachandran P., Gas Tables, Prentice-Hall of India Pvt. Limited, 2011

Text Books:

1. Balachandran P., Fundamentals of Compressible Fluid Dynamics, PHI Learning. 2006
2. Rathakrishnan E., Gas Dynamics, PHI Learning, 2014
3. Yahya S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International Publishers, 2003

References Books:

1. Anderson**,** Modern compressible flow, 3e McGraw Hill Education, 2012
2. Shapiro, Dynamics and Thermodynamics of Compressible Flow – Vol 1., John Wiley & Sons,1953

Course Plan			
Module	**Contents**	**Hours**	**End Sem. Exam Marks**
I	Introduction to Compressible Flow- Concept of continuum-system and control volume approach- conservation of mass, momentum and energy- stagnation state- compressibility-Entropy relations. Wave propagation- Acoustic velocity-Mach number-effect of Mach number on compressibility- Pressure coefficient-physical difference between incompressible, subsonic, sonic and supersonic flows- Mach cone-Sonic boom-Reference velocities- Impulse function-adiabatic energy equation-representation of various flow regimes on steady flow adiabatic ellipse.	8	15%
II	One dimensional steady isentropic flow- Adiabatic and isentropic flow of a perfect gas- basic equations- Area-Velocity relation using 1D approximation-nozzle and diffuser-mass flow rate-chocking in isentropic flow-flow coefficients and efficiency of nozzle and diffuser- working tables-charts and tables for isentropic flow-operation of nozzle under varying pressure ratios –over expansion and under expansion in nozzles.	7	15%
FIRST INTERNAL EXAM			
III	Irreversible discontinuity in supersonic flow- one dimensional shock wave- stationary normal shock- governing equations- Prandtl- Meyer relations- Shock strength- Rankine- Hugoniot Relation- Normal Shock on T-S diagram- working formula- curves and tables-Oblique shock waves - supersonic flow over compression and expansion corners (basic idea only).	7	15%
IV	Flow in a constant area duct with friction (Fanno Flow) – Governing Equations- Fanno line on h-s and P-v diagram- Fanno relation for a perfect gas- Chocking due to friction- working tables for Fanno flow- Isothermal flow(elementary treatment only)	6	15%
SECOND INTERNAL EXAM			
V	Flow through constant area duct with heat transfer (Rayleigh Flow)- Governing equations- Rayleigh line on h-s and P-v diagram- Rayleigh relation for perfect gas- maximum possible heat addition- location of maximum enthalpy point- thermal chocking- working tables for Rayleigh flow.	6	20%
VI	Compressible flow field visualization and measurement- Shadowgraph-Schlieren technique- interferometer- subsonic compressible flow field -measurement (Pressure, Velocity and Temperature) – compressibility - correction factor- hot wire anemometer- supersonic flow measurement- Shock tube-Rayleigh Pitot tube- wedge probe- stagnation temperature probe- temperature recovery factor –Kiel probe - Wind tunnels – closed and open type-	8	20%
END SEMESTER EXAM			

Question Paper Pattern

Use of approved gas tables permitted

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME431	MECHANICAL ENGINEERING LAB.	0-0-3-1	2016

Prerequisite : ME302 Heat and mass transfer, ME304 Dynamics of machinery

Course Objectives:

- To conduct the various heat transfer experiments
- To practice calibration of thermometer and pressure gauges
- To do experiments on dynamics

Syllabus

List of experiments:

Hear transfer

1. Determination of LMTD and effectiveness of parallel flow, Counter flow and cross flow heat exchangers(double pipe heat exchanger)
2. Determination of heat transfer coefficients in free convection(free convection apparatus)
3. Determination of heat transfer coefficients in forced convection (forced convection apparatus)
4. Determination of thermal conductivity of solids(composite wall)
5. Determination of thermal conductivity of powder
6. Determination of Thermal conductivity of liquids
7. Determination of emissivity of a specimen (emissivity apparatus)
8. Determination of Stefan Boltzman constant (Stefan Boltzmann apparatus)
9. Study and performance test on refrigeration (Refrigeration Test rig)
10. Study and performance test air conditioning equipment(air conditioning test rig)
11. Performance study on heat pipe(Heat pipe)
12. Calibration of Thermocouples
13. Calibration of Pressure gauge

Dynamics

14. Whirling of shaft
15. Gyroscope
16. Universal governor apparatus
17. Free vibration analysis
18. Forced vibration analysis

Note: Minimum 9 experiments in heat transfer and 3 experiments in dynamics are mandatory

Expected outcome:

The students will be able to

1. Conduct experiments to determine thermal conductivity of materials
2. Determine heat transfer coefficient, LMTD etc..
3. Do calibration of thermometers and pressure gauges
4. Demonstrate the effect of unbalances resulting from rotary motions
5. Visualise the effect of dynamics on vibrations in single and multi degree of freedom system
6. Demonstrate the working principle of governor /gyroscope and demonstrate the effect of forces and moments on their motion

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME461	**Aerospace Engineering**	**3-0-0-3**	**2016**
Prerequisite : Nil			

Course Objectives: :

- To understand the fundamentals of aerospace engineering
- To provide an understanding of flight instruments

Syllabus:

The atmosphere, airfoil theory, 2D, 3D or Finite aero foils Propellers, Aircraft performance, Flight Instruments, stability of aircrafts, wind tunnel testing

Expected Outcomes:

The students will be able to

i. Identify, formulate and solve aerospace engineering problems
ii. Perform analysis of flight dynamics of aircrafts

Text books:

1. A.C. Kermode, Mechanics of flight, Prentice Hall, 2007
2. Anderson, Fundamentals of Aerodynamics, McGraw-Hill, 2010
3. EHJ Pallett, Aircraft Instruments and Integrated systems, Longman,1992

Reference books:

1. Houghton and brock, Aerodynamics for Engineering Student, Hodder & Stoughton,1977

COURSE PLAN

Module	Contents	Hours	End Sem. Exam. Marks
I	The atmosphere-characteristics of troposphere , stratosphere , thermosphere, and ionosphere- pressure, temperature and density variations in the atmosphere. Application of dimensional analysis – aerodynamic force – model study and similitude. 2D aero foils -Nomenclature and classification- pressure distribution in inviscid and real flows- momentum and circulation theory of aerofoil- characteristics.	**8**	**15%**
II	3D or Finite aero foils – effect of releasing the wingtips- wing tip vortices- replacement of finite wing by horse shoe vertex system, lifting line theory-wing load distribution – aspect ratio, induced drag calculation of induced drag from momentum considerations. Skin friction and from drag- changes in finite wing plan shape	**7**	**15%**
FIRST INTERNAL EXAMINATION			

III	Propellers – momentum and blade element theories –propeller coefficients and charts. Aircraft performance-straight and level flight –power required and power available graphs for propeller and jet aircraft	**6**	**15%**
IV	Gliding and climbing –rate of climb-service and absolute ceilings-gliding angle and speed of flattest glide takeoff and landing performance – length of runway required- aircraft ground run- circling flight – radius of tightest turn-jet and rocket assisted take –off high lift devices-range and endurance of airplanes-charts for piston and jet engine aircrafts.	**7**	**15%**
SECOND INTERNAL EXAMINATION			
V	Flight Instruments-airspeed indicator, calculation of true air speed-altimeter, gyrohorizon -direction indicator-vertical speed indicator –turn and back indicator-air temperature indicator. (Brief description and qualitative ideas only). Ideas on stability-static and dynamic stability- longitudinal, lateral and directional stability- controls of an aero plane- aerodynamic balancing of control surfaces- mass balancing (Qualitative ideas only).	**7**	**20%**
V1	Principles of wind tunnel testing –open and closed type wind tunnels-wind tunnel balances supersonic wind tunnels. Study of subsonic, Transonic, and supersonic aircraft engines (Description with figures Only).Elementary ideas on space travel-calculation of earth orbiting and escape velocities ignoring air resistance and assuming circular orbit.	**7**	**20%**
END SEMESTER EXAMINATION			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A

There should be 2 questions each from module I and II

Each question carries 10 marks

Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B

There should be 2 questions each from module III and IV

Each question carries 10 marks

Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C

There should be 3 questions each from module V and VI

Each question carries 10 marks

Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME463	**Automobile Engineering**	**3-0-0-3**	**2016**

Pre requisites: Nil

Course objectives

- To know the anatomy of automobile in general
- To understand the working of different automotive systems and subsystems
- To update the latest developments in automobiles

Syllabus:- Engine, clutch, transmission, steering, brakes, suspension and aerodynamics

COURSE OUTCOMES:

The students will be able to:

i. Practically identify different automotive systems and subsystems.

ii. Understand the principles of transmission, suspension, steering and braking systems of an automobile

iii. Develop a strong base for understanding future developments in the automobile industry

Text Books

1. Gupta R.B. Auto design , Satya Prakash, New Delhi, 2015
2. Heinz Heisler, Advanced engine technology, Butterworth-Heinemann,1995
3. Heinz Heisler, Advanced vehicle technology, Society of Automotive Engineers Inc, 2002
4. Hillier and Peter Coobes, Fundamentals of motor vehicle technology, Nelson Thornes, 2004
5. Tom Denton, Automobile mechanical and electrical systems, Butterworth-Heinemann, 2011

Course Plan

Module	Contents	Hours	End Sem. Exam. Marks
I	Piston: - material for piston, clearances, piston rings, types, need for two compression rings, oil control ring, piston pin.	1	15%
	Piston for IC engine, piston rings, piston pin, connecting rod, crank shaft, crank pin, cam shaft, valves, fly wheel, fluctuation of energy and size of fly wheel, hub and arms, stress in a fly wheel rim, simple problems.	1	
		1	
	Petrol fuel injection systems: - comparison petrol injection and carbureted fuel supply systems- comparison –multiport fuel injection (MPFI) and common rail direct injection (CRDI) systems.	1	
		1	
	Super charging systems: fundamentals, naturally aspirated engines and supercharged engines– Turbo charger, turbo lag.	1	

	Hybrid cars, safety overview -Formula-I engine technology: overview, electrical technology, brakes, transmission technology.	1	
II	Friction clutch:- fundamentals, driven plate inertia, driven plate transmitted torque, driven plate wear –angular driven plate cushioning and torsional damping, clutch friction materials, when clutch is worn out.	1	**15%**
	Pull type diaphragm clutch, multiple diaphragm clutch, multi-plate hydraulically operated automatic transmission clutch, semi centrifugal clutch, fully automatic centrifugal clutch, and integral single plate diaphragm clutch.	1 1	
	Need of gear box, resistance to vehicle motion, power to weight ratio, speed operating range-five speed and reverse sliding mesh, constant mesh, and synchromesh gear boxes:- gear synchronization and engagement.	1 1	
	Over drives – hydrodynamic fluid couplings: - efficiency and torque capacity – fluid friction coupling- torque converters.	1 1	
FIRST INTERNAL EXAMINATION			
III	Steering:-basic principle of a steering system:- swinging beam system – Ackermann –over steer and under steer – slip angle, camber, caster etc.	1 1	**15%**
	Swivel axis inclination: centre point steering, camber, king pin inclination, negative offset, caster, toe-in and toe-out	1	
	Steering gear box: - fundamentals screw and nut steering gear mechanism-worm and roller type steering gear box – Re-circulating ball nut and rocker lever, re-circulating ball rack and sector steering gear box– need of power assisted steering.	1 1 1	
	External direct coupled and rack and pinion and integrated steering power cylinder, power assisted steering lock limitations	1	
IV	Suspension: - suspension geometry, terminology- Macpherson strut friction and spring offset - suspension roll centers:-roll centers, roll axis, roll centre height, short swing and long arm suspension, transverse double wishbone, parallel trailing double arm and vertical pill strut suspension, Macpherson strut suspension, semi-trailing arm rear suspension, telescopic suspension.	1 1	**15%**
	High load beam axle leaf spring, sprung body roll stability. Rear axle beam suspension- body roll stability analysis:- body roll couple, body roll stiffness, body over turning couple	1	

	Body weight transfer, body direct weight transfer couple, body roll couple distribution, body roll weight transfer, lateral force distribution.	1	
	Anti roll bars and roll stiffness:- anti roll bar function, operating principle, anti roll bar action caused by the body rolling, single wheel lift -rubber spring bumper:-bump stop function and characteristics, axis inclination.	1	
	Rear suspension: - live rigid axle suspension, non drive rear suspension- swing arm rear wheel drive independent suspension.	1	**15%**
	Low pivot split axle coil spring wheel drive independent suspension, trailing and semi trailing arm rear wheel drive independent suspension.	1	
	Transverse double link arm rear wheel drive independent suspension, De Dion axle rear wheel suspension - Hydrogen suspension, hydro-pneumatic automatic height correction suspension.	1	
SECOND INTERNAL EXAMINATION			
V	Brakes:- mechanical and hydraulic brakes (review only) – properties of friction lining and pad materials, efficiency, stopping distance, theory of internal shoe brake, equations – effect of expanding mechanism of shoes on total braking torque, equations.	1	**20%**
		1	
	Braking vehicles:- brakes applied on rear, front and all four wheels, equations –calculation of mean lining pressure and heat generation during braking operation, equations. – braking of vehicle moving on curved path, simple problems.	1	
		1	
	Anti Lock Braking system (ABS):- need and advantages of ABS – hydro-mechanical ABS - hydro-electric ABS - air-electric ABS.	1	
	Brake servos: - operating principle, vacuum servo - direct acting suspended vacuum assisted brake servo unit operation - hydraulic servo assisted brake systems.	1	
	Pneumatic operated disc brakes – air operated brake systems: - air over hydraulic brake system - Three line brake system-– electronic-pneumatic brakes.	1	
V1	Aerodynamic drag: pressure drag, air resistance, opposing motion of a vehicle, equations, after flow wake, drag coefficients, various body shapes, base drag, vortices, trailing vortex drag, attached transverse vortices.	1	**20%**
		1	
	Aerodynamic lift:-lift coefficients, vehicle lift, underbody floor height versus aerodynamic lift and drag, aerofoil lift and drag, front end nose shape.	1	
		1	
	Car body drag reduction:-profile edge chamfering, bonnet	1	

	slope and wind screen rake, roof and side panel chamfering, rear side panel taper, underbody rear end upward taper, rear end tail extension, underbody roughness.		
	Aerodynamic lift control:- underbody dams, exposed wheel air flow pattern, partial enclosed wheel air flow pattern, rear end spoiler, negative lift aerofoil wings.	1	
	After body drag: - square back drag, fast back drag, hatch back drag, notch back drag.	1	
END SEMESTER EXAMINATION			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3x10 marks =30 marks)

Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3x10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4x10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME465	**Industrial Hydraulics**	**3-0-0-3**	**2016**

Prerequisite : Nil

Course Objectives: :

1. To introduce various fluid power systems
2. To get knowledge on fluid power circuits

Syllabus:

Introduction to fluid power, Properties of fluids. Selection of fluids, Pumps, Hydraulic cylinders and rams, Fluid power pumping systems and components, Hydraulic Actuators, Fluid temperature control, Piping systems, Control circuits

Expected Outcomes:

The students will be able

1. To understand the various components used in fluid power systems
2. To select the suitable system for a particular application
3. To know the various fluid circuits used in hydraulic systems

Text books:

1. B. Lall, Oil Hydraulics, International Literature Association
2. D. A. Pease, Basic Fluid Power, Prentice Hall,1986
3. J. J. Pipenger, Tyler Gregory Hicks, Industrial Hydraulics, McGraw Hill,1979
4. Pinches, Industrial Fluid Power, Prentice Hall,1989
5. R.K. Bansal, Fluid Mechanics, Laxmi Publication (P) Ltd.,2017

Reference:

1. ISO - 1219, Fluid Systems and components, Graphic Symbols
2. Andrew A. Parr, Hydraulics and Pneumatics, Elsevier ,1999
3. Michael J. Prinches and Ashby J. G, Power Hydraulics, Prentice Hall,1988
4. Yeaple, Fluid Power Design Handbook, CRC Press,1995

COURSE PLAN

Module	Contents	Hours	End Sem. Exam. Marks
I	Introduction to fluid power – Hydraulics and Pneumatics systems – Fluid power systems – Fundamentals of fluid mechanics , Properties of fluids. Selection of fluids, additives, effect of temperature and pressure on hydraulic fluids , Measurement of physical parameters – Hydraulic symbols	**7**	**15%**
II	Pumps: Types , classification , principle of working & constructional details of vane pump, gear pumps, radial and axial plunger pumps, Power and efficiency calculations, char, Curves, selection of pumps for hydraulic power transmission	**7**	**15%**

FIRST INTERNAL EXAMINATION

III	Hydraulic cylinders and rams – Fluid power pumping systems and components. Pressure accumulators – Functions – Fluid reservoirs – Filter in hydraulic circuits. Loading and replacement of filter elements – Materials for filters.	**7**	**15%**
IV	Hydraulic Actuators (i) Linear and Rotary. (ii) Hydraulic motors - Types- Vane, Gear, Piston types, radial piston. (iii) Methods of control of acceleration, deceleration. (iv) Types of cylinders and mountings. (v) Calculation of piston velocity, thrust under static and dynamic applications, considering friction, inertia loads. (vi) Design considerations for cylinders. Cushioning of cylinders.	**7**	**15%**
SECOND INTERNAL EXAMINATION			
V	Fluid temperature control – Fluid pressure control –control valves – Sequence -valve – Counterbalance valve-unloading valve – Friction control valve – Servo systems, Hoses & Pipes : Types , materials , pressure drop in hoses/pipes. Hydraulic piping connections.	**7**	**20%**
V1	Simple reciprocating, Regenerative, Speed control (Meter in, Meter out and bleed off), Sequencing, Synchronization, transverse and feed, circuit for riveting machine, automatic reciprocating, fail safe circuit, counter balance circuit, actuator locking, circuit for hydraulic press, unloading circuit (Numerical treatment), motor breaking circuit	**7**	**20%**
END SEMESTER EXAMINATION			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A

There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B

There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C

There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME467	**Cryogenic Engineering**	**3-0-0-3**	**2016**

Prerequisite : NIL

Course Objectives: :

- To provide the knowledge of evolution of low temperature science
- To provide knowledge on the properties of materials at low temperature
- To familiarize with various gas liquefaction systems and to provide design aspects of cryogenic storage and transfer lines

Syllabus:

Introduction to Cryogenics, Applications of Cryogenics, Properties of materials at cryogenic temperature, Liquefaction systems, Gas liquefaction systems, Cryogenic Refrigeration systems, Cryogenic fluid storage and transfer systems, Cryogenic instrumentation, heat exchangers used in cryogenic systems

Expected Outcomes:

The students will be able to

i. Understand properties of material at cryogenic temperatures.
ii. Know about various liquefaction systems
iii. Get ideas on cryogenic refrigeration systems, cryogenic instrumentation and cryogenic heat exchangers

Text books

1. J. H. Boll Jr, Cryogenic Engineering
2. R. B. Scott, Cryogenic Engineering, Van Nostrand Co., 1959
3. Randal F.Barron, Cryogenic systems, McGraw Hill, 1986

Reference books:

1. Klaus D.Timmerhaus and Thomas M.Flynn, Cryogenic Process Engineering, Plenum Press, New York, 1989.

Module	Contents	Hours	End Sem. Exam. Marks
I	Introduction to Cryogenic Systems, Historical development, Low Temperature properties of Engineering Materials, Mechanical properties- Thermal properties- Electric and magnetic properties – Cryogenic fluids and their properties. Applications of Cryogenics: Applications in space, Food Processing, super conductivity, Electrical Power, Biology, Medicine, Electronics and Cutting Tool Industry. Low temperature properties of engineering materials	**8**	**15%**
II	Liquefaction systems ideal system, Joule Thomson expansion, Adiabatic expansion, Linde Hampson Cycle, Claude & Cascaded System, Magnetic Cooling, Stirling Cycle Cryo Coolers.	**7**	**15%**
FIRST INTERNAL EXAMINATION			

III	Gas liquefaction systems: Introduction-Production of low temperatures-General Liquefaction systems- Liquefaction systems for Neon. Hydrogen and Helium –Critical components of Liquefaction systems	**6**	**15%**
IV	Cryogenic Refrigeration systems: Ideal Refrigeration systems-Refrigeration using liquids and gases as refrigerant- Refrigerators using solids as working media;,	**6**	**15%**
SECOND INTERNAL EXAMINATION			
V	Cryogenic fluid storage and transfer systems: Cryogenic Storage vessels and Transportation, Thermal insulation and their performance at cryogenic temperatures, Super Insulations, Vacuum insulation, Powder insulation, Cryogenic fluid transfer systems.	**8**	**20%**
V1	Cryogenic instrumentation, Pressure flow-level and temperature measurements. Types of heat exchangers used in cryogenic systems(only description with figure) Cryo pumping Applications	**7**	**20%**
END SEMESTER EXAMINATION			

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A

There should be 2 questions each from module I and II
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part B

There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C

There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME469	FINITE ELEMENT ANALYSIS	3-0-0-3	2016

Prerequisite : Nil

Course Objectives

1. To learn the mathematical background of finite element methods.
2. To understand the basics of finite element formulation.
3. To practice finite element methodologies through structural and heat transfer problems.

Syllabus

Introduction; Brief history; Review of elasticity; Direct approach;1D bar element; Analogous problems; Beam elements; Plane truss; Coordinate transformations; Interpolation functions; Shape functions; Variational methods; Strong and weak form; Rayleigh Ritz method; FE formulation using minimization of potential; Consistent nodal loads; Higher order elements; Iso parametric elements; Weighted residual methods; FEA software packages.

Expected outcome

The students will be able to

i. understand the mathematical background of FEM .
ii. solve real life problems using finite element analysis

Text Books:

1. Chandrupatla T R., Finite Element Analysis for Engineering and Technology, University Press, 2004
2. Hutton D V., Fundamentals of Finite Element Analysis, Tata McGraw-Hill, 2005
3. Logan D L., A first course in the Finite Element Method, Thomson-Engineering, 2012
4. Seshu P., Text Book of Finite Element Analysis, PHI Learning Pvt. Ltd., 2003

References Books:

1. Cook R D., Malkus D S., Plesha M E.,Witt R J., Concepts and Analysis of Finite Element Applications, John Wiley & Sons,1981
2. Reddy J N., An introduction to the Finite Element Method, McGraw- Hill, 2006

Course

Module	Contents	Hours	End Sem. Exam Marks
I	Introduction to Finite Element Method (FEM)- Brief history- Application of FEA- Advantages and disadvantages. Review of elasticity- Strain displacement relations- Compatibility-Stress strain relations- Boundary conditions- Plane stress, plane strain and axisymmetry.	2	15%

	Direct approach-1D bar element- element stiffness- Assembly of elements- properties of [K] matrix- Treatment of boundary conditions- Stress computation.	4	
II	Analogous problems of torsion, heat conduction and laminar pipe flow. Beam elements- FE formulation-element stiffness matrix- boundary conditions.	4	20%
	Plane truss- Element formulation-Co ordinate transformation- Local and global co ordinates- Stress calculations.	4	
FIRST INTERNAL EXAMINATION			
III	Interpolation functions-Shape functions- Lagrange interpolation- 1D linear and quadratic element	3	15%
	Variational methods: Functionals- Strong and weak form- Essential and natural boundary conditions.	3	
IV	Principle of stationary potential energy- Rayleigh Ritz method.	3	20%
	FE formulation using minimization of potential- B matrix- Element matrices for bar element- Consistent nodal loads.	4	
SECOND INTERNAL EXAMINATION			
V	Higher order elements- Quadratic and cubic elements-Pascal's triangle- Serendipity elements.	3	15%
	Iso parametric elements, Natural coordinates, Area co ordinates- Quadrilateral elements-Jacobian matrix-Gauss quadrature.	5	
VI	Weighted residual method: Galerkin FE formulation. Axially loaded bar- Heat flow in a bar	5	15%
	Structure of FEA software package. Introduction to Modal analysis, non linear analysis and coupled analysis.	2	
END SEMESTER EXAMINATION			

Question Paper Pattern

Maximum marks: 100, **Time: 3 hrs**

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Each question carries 10 marks
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Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3X10 marks =30 marks)

Part C

There should be 3 questions each from module V and VI

Each question carries 10 marks

Students will have to answer any four questions out of 6 (4X10 marks =40 marks)

Note: Each question can have a maximum of four sub questions, if needed.

Course code	Course Name	L-T-P-Credits	Year of Introduction
ME471	**Optimization Techniques**	**3-0-0-3**	**2016**

Prerequisite - ME372 Operations Research

Course Objective:

- To learn the various optimization techniques for effective decision making.

Syllabus:

Linear programming – integer programming– network models – goal programming – dynamic programming – nonlinear programming – nontraditional optimization.

Expected Outcome:

- The students will be able to understand optimization techniques and apply them in solving practical problems

Text Books:

1. Miller, D. M. and Schmidt, J. W., Industrial Engineering and Operations Research, John Wiley & Sons, Singapore, 1990.
2. Paneerselvam, R., Operations Research, Prentice Hall of India, New Delhi, 2008.
3. Pannerselvam, R., Design and Analysis of Algorithms, Prentice Hall of India, New Delhi, 2007.
4. Taha, H. A., Operations Research, Pearson, 2004.

Reference Books:

1. Banks, J., Carson, J. S., Nelson, B. L., and Nicol, D. M., Discrete-Event System Simulation, Third Edition, Pearson Education, Inc., 2001
2. Goel, B. S. and Mittal, S. K., Operations Research, Pragati Prakashan, Meerut, 1999.
3. Ravindran, Phillips and Solberg, Operations Research Principles and Practice, Willey & Sons, 1987
5. Srinivasan, G. "Operations Research-Principles and Applications", latest edition, PHI Pvt. Ltd.

Course Plan

Module	Contents	Hours	End Sem. Exam. Marks
I	Review of linear programming– revised simplex method	**1**	**15%**
		1	
	Dual simplex method	**1**	

		1	
	Sensitivity analysis – changes affecting feasibility – changes affecting optimality	1	
		1	
		1	
II	Integer programming – importance – applications	1	15%
	Branch and bound technique	1	
		1	
	Gomory's cutting plane method	1	
		1	
	Solution to travelling salesman problem	1	
		1	
FIRST INTERNAL EXAMINATION			
III	Network models – minimal spanning tree problem	1	15%
	PRIM's algorithm	1	
	Kruskal's algorithm	1	
	Shortest route problem –applications	1	
	Systematic method	1	
	Dijkstra's algorithm	1	
	Floyd's algorithm	1	
IV	Goal programming – goal programming formulation-application.	1	15%
		1	
	Simplex method for solving goal programming	1	
		1	
	Dynamic programming – terminologies – forward and backward recursion –applications	1	
	Shortest path problems	1	
		1	
SECOND INTERNAL EXAMINATION			
V	Nonlinear programming – convex, quasi-convex, concave and unimodal functions – theory of constrained optimization	1	20%
		1	
		1	
	Lagrangean method	1	
		1	
	Kuhn-Tucker conditions	1	
		1	
VI	Nontraditional optimization – computational complexity- Introduction to metaheuristics – areas of application	1	20%
		1	
	Genetic algorithm (GA) – terminologies – steps and examples	1	
	Tabu search (TS) – steps and examples	1	
	Simulated annealing (SA) – steps and examples	1	
	Ant colony optimization (ACO) – steps and examples - Particle Swarm Optimization (PSO)-Steps and examples	1	
		1	

Question Paper Pattern

Maximum marks: 100 **Time: 3 hrs**

The question paper should consist of three parts

Part A
There should be 2 questions each from module I and II
Each question carries 10 marks
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Part B
There should be 2 questions each from module III and IV
Each question carries 10 marks
Students will have to answer any three questions out of 4 (3x10 marks =30 marks)

Part C
There should be 3 questions each from module V and VI
Each question carries 10 marks
Students will have to answer any four questions out of 6 (4x10 marks =40 marks)

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