DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY (ISM) DHANABD

SYLLABUS OF M.TECH (MECHANICAL ENGINEERING)

SPECIALIZATION: MAINTENANCE ENGINEERING AND TRIBOLOGY(MET)

FIRST SEMESTER					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
DEPARTMENTAL CORE					
		3	0	0	9
MEC519	Engineering Tribology	3	0	0	9
MEC520	Tribology Based Maintenance Engineering	3	0	0	9
MEC521	Theory of Lubrication	3	0	0	9
MEC522	Condition Monitoring of Machines	3	0	0	9
PRACTICALS					
MEC523	Tribology Lab	0	0	3	3
MEC524	Condition Monitoring Lab	0	0	2	2
	Total	**15**	**0**	**5**	**50**

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC 502	**Numerical Methods**	3	0	0	9

Course Objective

The objective of the course is to study the numerical solution of linear and non-linear algebraic equations, solution of differentiation, integrations, PDE and ODEs.

Learning Outcomes

Upon successful completion of this course, students will:

- Be able to solve actual problems by using different Numerical methods.
- Be able to use FDM for discretization of governing equations to find the temperature distribution in the given geometry
- Be able to understand the different types of PDEs
- Be able to use the upwinding for solving the flow problems.
- Be able to write the computer programming based on learning of this course

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to Numerical Methods,	1	Numerical Methods are gradually becoming the substitute of

			experimental methods.
2	Solution of linear algebraic systems: Non-iterative method, Gauss elimination method, LU- factorization method, Matrix inversion method. iterative method, Gauss Seidel iterative method, Jacobi method, ill - conditioning problems, Tridiagonalization, Hoseholder's method, QR-factorization	8	This unit will help students in understanding the numerical solution methodology for linear equations
3	Solution of non-linear algebraic systems: Solution of equations by iterations, Fixed point iterations, Newton's method, Secant method, Bi-section method	5	Understanding the methods for solution of non-linear equations.
4	Numerical differentiation: Methods for first order ODEs, Euler method, Runge-Kutta methods, Methods for higher order and systems of ODEs, Euler method, Runge-Kutta methods, Stiff systems	5	This unit will help students in understanding the applications of Euler's Method, R-K2 and higher order R-K 4 methods
5	Numerical integration: Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. Numerical double integration	5	Numerical integrations will be very useful for summation and averaging. Also, students will learn about best technique for integration.
6	Introduction to partial differential equations: 1^{ST} Order PDEs, Mathematical classification second order PDEs, Characteristics.	2	Understanding the behavior of PDE equations.
7	Finite Difference Methods: Different discretization techniques of PDE equations, Backward, forward and central differencing discretization schemes, Euler's explicit, implicit and semi-implicit methods, Truncation, Discretization, Round off errors. Consistency, stability and convergence. Fourier or von-Neumann stability analysis of Finite difference schemes.	8	Understanding different types of errors, consistency, stability and convergence during solving the governing equations.
8	Applications to model problems: Parabolic equations, heat equations, Elliptic equations, Laplace and Poisson's equations. Dirichlet problems, ADI method, Neumann and Mixed problems, Hyperbolic equation, wave equation, Upwinding differencing schenie of advection terms.	5	Students may use different methods for solving the actual heat and fluid flow and wave equations,

Text Books:

1. Introductory Methods of Numerical Analysis: S.S.Sastry, 4^{th} Edition, Prentice Hall of India Pvt Ltd,
2. Computational Methods in Engineering: S.P.Venkateshan, P Swaminathan, Ane Books Pvt Ltd

Reference Books:

3. Numerical Solution of Partial Differential Equations: G.D.Smith, Oxford University Press, 1985
4. Computational Fluid Mechanics and Heat Transfer: D.A.Anderson, J.C.Tannehill and R.H.Pletcher, Hemisphere Publishing Corporation

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC519	**Engineering Tribology**	3	0	0	9

Course Objective
To understand the application of Tribology in modern machinery for designing, manufacturing and exploration for new and better products.
Learning Outcomes
Upon successful completion of this course, students will: • Be able to know the field of tribology. • Be able to know the surface, properties of surface and related instruments

- Be able to understand the friction, friction theory and behaviour of metals and non-metals
- Be able to understand wear processes, wear theory, behaviour of metals and non-metals and different instruments
- Be able to understand the lubricants, lubrication and instruments for measuring lubricant's properties.

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Friction, Wear and Lubrication.	2	Introduce the students to the field of tribology
2	Engineering Surfaces – Properties and Measurement; Typical surface layers, Measurement Methods (Surface Profilometry, Optical Microscopy, Electron Microscopy), Surface Contact.	6	Students will learn about the surface, properties of surface and related instruments.
3	Friction: Measurement Methods, Adhesion, Deformation, Friction Theories, Stick-slip, Rolling Friction, Friction of Metals, Friction of Non-Metallic Materials.	7	Students will learn basic understanding of friction, become familiar with common friction theory and friction behaviour of metals and non-metals.
4	Wear: Types of Wear and its Mechanisms (Adhesive Wear, Abrasive Wear, Erosive Wear, Corrosive/Oxidative Wear, Fatigue Wear), Wear of Metals, Wear of Ceramics, Wear of Polymers, Wear Test (Pin on Disc Tribometer, Reciprocating Tribometer), Wear reduction methods.	10	Students will learn basic understanding of wear processes, wear theory, wear behaviour of metals and non-metals and learn different instruments for measuring friction and wear.
5	Lubricants and Lubrication: Lubricants and their types, Purpose of Lubrication, General Properties of Liquid Lubricants, Animal and Vegetable Oils, Mineral oils, Synthetic oils, Blended Oils, Lubricant Additives, Semi Solid Lubricant or Greases, Solid Lubricants, Testing of Lubricants (Viscometer, Four Ball Tester).	10	Students will learn basic understanding of lubricants, lubrication and learn different instruments for measuring lubricant's properties.
6	Case studies on friction, wear and lubrication using ANSYS.	4	Students will learn the behaviour of tribological components by software.

Textbooks

1. Engineering Tribology, Gwidon W. Stachowiak and Andrew W. Batchelor, 4th Edition,2014
2. Tribology: Friction and Wear of Engineering Materials, Ian Hutchings and Philip Shipway, 2nd Edition, 2017

References

1. Introduction to Tribology , Bharat Bhushan, Wiley, 2nd Edition, 2002
2. Engineering Tribology by. Prasanth Sahoo, Prentice Hall India Learning Private Limited, 2005
3. Fundamentals of Tribology, Ramsay Gohar and Homer Rahnejat, Imperial College Press, 2nd Edition, 2012

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC520	**Tribology based Maintenance Engineering**	3	0	0	9

Course Objective

The objective of the course is to impart knowledge of maintenance Engineering to students in order to help industries solve maintenance related problems

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Learning Outcomes

Upon successful completion of this course, students will:

- Be able to understand basics of maintenance engineering.
- Be able to learn various types of maintenance.
- Be able to learn about various tests and analyses for maintenance
- Be able to know about lubricants used in maintenance of machines.
- Be able to solve problems related to maintenance of machines in the industries by use of maintenance software

Module	Topics	Lecture Hours	Learning Outcome
1	Maintenance: Key to reliability and productivity, Basic elements of maintenance system - inspection, planning & scheduling, job execution, record keeping, learning & improvement, Data collection and analysis	5	This unit will help learn basics of tribology based maintenance engineering.
2	Basic definitions - preventive, operating and shutdown maintenance; Condition based maintenance and condition monitoring. Application of preventive maintenance for system of equipment, Bath tub curve	6	This unit will help students in gaining knowledge about various types of maintenance.
3	Vibration and signature analysis; causes, remedy in rotating machinery, Fluid analysis for condition monitoring, various methods of fluid analysis.	7	Understanding of various analyses for maintenance.
4	Non-destructive test: dye-penetrant test, magnetic particle test and ultrasonic tests.	4	This unit will help students in learning about types of tests
5	Science of friction and wear, Different types of wear	7	This unit will help in learning about friction and wear.
6	Lubrication: Introduction to lubrication engineering, types, classification of lubricants with their properties and characteristics. Bearing lubrication technique for minimization of friction and wear.	7	This unit will help students to learn about lubricants and additives, their properties and applications.
7	Introduction to computer-aided maintenance management system (CMMS). CMMS Software, Case studies	3	This unit will help students to learn about real life situations and application software.

Textbook

1. Introduction to Maintenance Engineering: Modeling, Optimization, and Management Mohammed Ben-DayaUday Kumar D.N. Prabhakar Murthy 2016 John Wiley & Sons, Ltd.

Reference Book/software.

2. Maintenance Engineering Sushil Kumar Srivastava 2010 S. CHAND Publishing

3. CMMS Software

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC521	Theory of Lubrication	3	0	0	9

Course Objective

Objective of this course is to understand the fundamental of lubrication and mechanics of different lubrication regimes and to develop ability to solve various tribological problems in Industry related to lubrication.

Learning Outcomes

Upon successful completion of this course, students will:

- have a broad understanding of theory of lubrication.
- be able to determine the performance parameters of hydrodynamic bearings, squeeze film bearings, Hydrostatic bearings.
- be able to understand lubrication of rolling element bearings.
- be able to solve lubrication issues of industry.

Module	Topics	Lecture Hours	Learning outcomes
1	Lubrication regimes, Viscosity and the rheology of lubricants. Mechanics of Lubricant Film: Momentum equation, Navier-Stokes equation, Continuity equation, Energy equation, Reynolds equation, Lubricant flow, Shear forces, Reynolds equation for power law fluids.	7	Basic concept of theory of Lubrication and related equations.
2	Hydrodynamic Lubrication: Hydrodynamic Thrust Pad Bearing (ILA and ISA), Hydrodynamic Journal Bearing (ILA & ISA), Finite Bearing, Mechanism of hydrodynamic instability, Dynamic characteristics of hydrodynamic journal bearings.	12	Ability to analyze and design hydrodynamic sliding element bearing
3	Squeeze film Lubrication : Squeeze film of planer, non-planer, and finite surfaces.	5	Understanding of squeeze film lubrication and its application
4	Hydrostatic Lubrication: Circular step externally pressurized thrust bearing (capillary and orifice compensated), Externally pressurized multi-recess journal bearing with short and large sill dimensions**.**	7	Ability to analyze and design different types of hydrostatic bearings
5	Elasto-hydrodynamic Lubrication: Introduction, EHL under Line and Point contact, Different regimes in EHL contacts, Mixed Lubrication.	8	Understanding of Elastohydrodynamic lubrication in different machine components

Text Books:

1. Theory of Lubrication : Ghosh , Mazumdar, and Sarangi, Tata McGraw Hill Education.; 1st edition , 2013

Reference Books:

1. Applied Tribology- Bearing Design and Lubrication: M M Khonsari and E R Booser, John Wiley & Sons; 3rd edition, 2017
2. Engineering Tribology by GwidonW. Stachowiak and Andrew W. Batchelor, 4th Edition, 2014.
3. Fundamental of Fluid Film Lubrication: B J Hamrock, S R Schimid, and B O Jacobson, Marcel Dekker Inc. 200

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC522	**Condition Monitoring of Machines**	3	0	0	9

Course Objective

The objective of the course is to study the Basics of condition monitoring techniques and the signal processing techniques associated with the instruments used in vibration monitoring, oil analysis etc., its application in industries, case studies related to the condition monitoring of machines and its advantages.

Learning Outcomes

Upon successful completion of this course, students will:

- Be able familiar to condition monitoring technique and its methods.
- Be able to identify the instruments which may be employed for diagnosis of failures.
- Be able to understand diagnose the failures and its consequences and therefore importance of condition monitoring techniques.
- Be able to use the instruments and basic signal processing terminology used while handling the instruments.
- Be able to diagnose a particular failures and will be able to reach to root cause of the failures in machines.

Module	Topics	Lecture Hours	Learning Outcome

1	Maintenance and Condition Monitoring: Importance and necessity of maintenance, Different maintenance strategies	5	This will familiarise with condition monitoring and its importance in industries.
2	Techniques of condition monitoring: Different Nondestructive techniques – Visual, Dye Penetration, Acoustic Emission and its applications, X-ray, Radiographic, Magnetic Flux test, Temperature monitoring, Vibration analysis, Oil analysis	4	This unit will help students in understanding the basic condition monitoring techniques prevailing in the industries.
3	Oil Analysis – Oil degradation analysis, Abrasive Particle in oil, counters, Particle classification and counter, Spectrometric oil analysis, Performance trend monitoring – Primary and secondary parameters, Ferrography, Corrosion monitoring techniques	10	This will give in an insight of the oil analysis, it parameters used to observe, instruments used in oil analysis.
4	Vibration Measurement – Different sensors for sound and vibration measurement, Data acquisition, Noise and vibration analyzers, Laser vibrometer, Vibration limits & Standards	5	This unit will help students in understanding the basic instruments, basic characteristics and their applications in industries.
5	Basic signal processing techniques: Fourier analysis, Hilbert Transform, Cepstrum analysis, Digital filtering, Time-frequency analysis, Shock pulse method, Kurtosis.	5	This chapters will familiarise students with various signal processing terms used in the vibration analysis during data acquisition and its post processing techniques.
6	Condition monitoring of rotating machines: Bearing condition monitoring, gear condition monitoring, Critical speed analysis, Orbit Analysis, Wear behaviour monitoring, Faults in reciprocating machines, Case studies and failure analyses	10	This chapter will help the students to understand the in-depth analysis of the failures of bearings, wear, gears etc.

Text Books:

5. Robert Bond Randall, Vibration based condition monitoring: Industrial aerospace and automotive applications: Willey publication 2010.
6. Cornelius Scheffer, Paresh Girdhar (2004), Machinery Vibration Analysis & Predictive Maintenance, Elsevier Publication

Reference Books:

1. Rao, B. (1996), Handbook of condition monitoring, Elsevier advanced technology, Oxford.
2. Amiya Ranjan Mohanty, Machinery Condition Monitoring and Principles.(1st edition) 2014Computational Fluid
3. Mechanics and Heat Transfer: D.A. Anderson, J.C. Tannehill and R. H. Pletcher, Hemisphere Publishing Corporation

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC523	**Tribology Lab**	0	0	3	3

List of Practicals

1. Qualitative Analysis of Wear Debris using Ferrography.
2. Measurement of wear and coefficient of friction using Pin on Disk.
3. Viscosity Measurement of lubricant.
4. Flash Point and Fire Point Measurement of Lubricating oil
5. Cloud Point and Pour Point Measurement of Lubricating oil
6. Water Content Measurement of Lubricating oil
7. TAN/TBN measurement of Lubricating oil
8. Simulation and Modelling of Tribo Pairs
9. Quantitative Analysis of Wear Particles Using Software
10. Experimental study on Nanolubricants.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC524	**Condition Monitoring Lab**	0	0	2	2

List of Practicals

1. Vibration signature of different bearing faults
2. Vibration signature of different gear faults
3. Cepstrum analysis of vibration signal for fault identification
4. Model Analysis of cantilever beam
5. Condition monitoring using temperature measurement
6. Envelop analysis for fault detection
7. Kurtosis analysis for fault detection
8. Experimental analysis of resonance in the machine using FFT analyser.
9. Study of sound absorbing material using Noise analyser.
10. Study of single plane and two plane balancing in rigid rotors using vibration parameters
11. Crack detection in the machine components using vibration parameters.
12. Study of Noise generation in various conditions (ambient, on rod, in office etc.)

2ND Semester

Course No.	Course Name	L	T	P	CH
	Departmental Electives(any Three)				

	Basket 1				
MED527	Design of Tribological Components	3	0	0	9
MED533	Acoustics and Noise Control	3	0	0	9
MED562	Failure Analysis and Repair	3	0	0	9
	Basket 2				
MED554	Surface Engineering	3	0	0	9
MED563	Reliability, Availability and Maintainability Engineering	3	0	0	9
MED564	Erosion and Corrosion of Machine Components	3	0	0	9
	Basket 3				
MED565	Nano Technology in Tribology	3	0	0	9
MED566	Simulation in Maintenance Engineering and Tribology	3	0	0	9
MED 529	Composite Material	3	0	0	9
	Open Elective(any Two)				
MEO 588	Risk Analysis and Safety	3	0	0	9
MEO 589	Maintenance audit	3	0	0	9
	Practicals				
MEC 567	Tribological Design Lab	0	0	3	3
MEC 568	Tribology Based Maintenance Engineering Lab	0	0	2	2
	Total	15	0	5	50

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED527	**Design of Tribological Components**	3	0	0	9

Course Objective
The main objective of this course is to promote a better appreciation of the increasingly important role played by tribology at design stage in engineering. It will help in implementing algorithms developed from the basic principles of tribology to a wide range of practical application.
Learning Outcomes
Upon successful completion of this course, students should be able to:

- Implement the concept of tribology at the design stage of a mechanical components such as rolling element bearing, gears, seals, clutches , brakes and belt drive
- solve industrial problem related to tribological components
- Identify a suitable research topic to solve realistic industrial problem

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: Tribological consideration in design, Conceptual design, Classification of tribological components, Mechanisms of tribological failures in machines, Zero wear concept, Computational techniques in design	3	Concept of tribology at the design stage
2	Rolling Element Bearings: Selecting bearing types and size, Principles and operating limits, Friction and Elastohydrodynamic Lubrication	9	Ability to Select of rolling element bearing for a particular application
3	Dry and Starved Bearings: Dry and semi lubricated bearings, analysis of partially starved bearings, minimum oil supply and temperature of starved bearings	5	Ability to analyse the bearing under different operating situation
4	Gas Lubricated Bearings: Thrust Bearing, Journal bearings, porous bearing	6	Concept of gas lubricated bearing
5	Seal Fundamentals: Classification of seals, Clearance seals, Visco seals, Radial contact seals, Mechanical face seals	5	Ability to design a seal
6	Tribology of Gears: Spur gears, friction and wear of spur gears, contact stresses, lubrication of spur gears, surface failures	4	ability to design a gear for a particular application
7	Design of Dry Frictional Elements: Dry friction concepts, Brakes and Clutches, Friction belts and Dry rubbing bearing	7	Ability to analyse and design clutches brakes and belt drives

Textbooks

1. M M Khonsari and E R Booser,,Applied Tribology: Bearing Design and Lubrication, John Wiley & Sons, 3rd Ed.2017.
2. H Hirani, Fundamentals of Engineering Tribology with Applications, Cambridge University press, 1st Ed.2016.

References

1. G W Stachowiak and A W Batchelor, Engineering Tribology, Butter Worth & Heinemann Publication, 3rd Ed.2005.
2. Ghosh , Mazumdar, and Sarangi, Theory of Lubrication, Tata McGraw Hill Education, 1st Ed.2013.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED529	**Composite Materials**	3	0	0	9

Course Objective

- To learn the properties of fiber-reinforced polymer composites
- To learn the mechanical performance of laminated composites, including failure behavior.
- To model, simulate and optimize the performance of composite structures.

Learning Outcomes

Upon successful completion of this course, students will able to:

- Identify, describe and evaluate the properties of fibre reinforcements, polymer matrix materials and commercial composites.
- Develop competency in one or more common composite manufacturing techniques, and be able to select the appropriate technique for manufacture of fibre-reinforced composite products.
- Analyse the elastic properties and simulate the mechanical performance of composite laminates; and understand and predict the failure behaviour of fibre-reinforced composites
- Apply knowledge of composite mechanical performance and manufacturing methods to a composites design project

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to composites: Brief History, Constituent Materials, Laminate , FRP, micro-mechanics & macro-mechanics, Applications	2	Understand the Composite, its advantage, classification and the terminology used for studying mechanics of composites
2	Fabrication: Liquid resin impregnation routes, Pre-Pregs methods, Consolidation of resin moulding compounds, Injection moulding and hot pressing of thermoplastics. Fabrication of metal matrix composite.	4	Understanding the manufacturing process of composite
3	Micromechanical Analysis: Assumptions, strength-stiffness, Shear , Poisson Ration	6	Develop concepts of volume and weight fraction of fiber and matrix, density and void fraction in composites
4	Elastic Properties of Unidirectional Lamina: , stress – strain relations for general anisotropic, specially orthotropic and transversely isotropic materials, Transformation Matrix	7	Find the engineering constants; Develop stress-strain relationships, elastic moduli, strengths of a unidirectional/bidirectional lamina
5	Analysis of Laminated Composites: Classical Laminate Theory, Displacement Field, Strain Displacements Relations, Constitutive Relations, Classification of Laminates and their properties.	8	Find the elastic stiffnesses of laminate based on the elastic moduli of individual laminas and the stacking sequence
6	Analysis of Laminated Plate & FEM: Classical Plate theory, Bending of composite plate, Shear deformation theories: FSDT, HSDT, Layerwise	6	Ability to analyze problems on bending, buckling, and vibration of laminated plates and beams
7	Hygrothermal Effects of Laminates , Failure Theories and Strength of Unidirectional Lamina Design of Composite structure & Example	6	Develop the relationships of mechanical and hygrothermal loads applied to a laminate to strains and stresses in each lamina

Text:

1. Mechanics of Composite Material & Structures, M Mukhopadhyay, Universities press 2013.

References:

1. An Introduction to Composite Materials, By D. Hull and Clyne, Cambridge University Press 2010
2. Engineering mechanics of composite materials, I. M. Daniel & O. Ishai, 2nd edn., oxford university press, 2006.
3. Principles of composite material mechanics, R. F. Gibson, 2nd edn. CRC Press, 2007.
4. Mechanics of Composite Material, Autar K. Kaw, CRC Press
5. Mechanics of composite materials, Rr. M. Jones, 2nd edn. Taylor & francis, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 533	**Acoustics and Noise control**	3	0	0	9

Course Objective

- Noise and Harshness has become a major issue in today's society, which calls for a quitter technology.
- This course will be extremely useful for engineers and researchers to design quitter machines or machine components.

Learning Outcomes

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

- Understand the concept of technical acoustics
- Apply the concept in solving industrial problems
- Develop software code for a proper mathematical modeling

- Identify a suitable research topic to solve realistic industrial problem

Module	Topics	Lecture Hours	Learning Outcome
1	Fundamentals of vibration, Sound and vibration, Acoustics and engineers, basics of acoustics, dB levels, Concept of acoustic impedance etc.	5	Brush up of Vibration fundamentals. Introducing acoustics to aspiring engineers.
2	Type of waves, Characteristic of waves, Mathematical models of sound waves, 3D Wave equation,	6	Acoustic wave phenomena and developing various mathematical models.
3	Acoustics of cavity, Helmholtz resonator, noise control techniques, Noise Control Application, Acoustics of Mufflers etc.	8	Different types of noise control techniques and devices.
4	Experimental Techniques, Source Modeling, Acoustic Structure Interaction, Sound Radiation from Vibrating Infinite Plate.	8	Learning how sound interact with different structures and quantifying sound radiation from the structure.
5	Types of Microphones and specifications, Octave bands.	2	Introducing sensors to pickup acoustic signals and their analysis.
6	Wavenumber space, K-Space Diagram, Concept of Angular Spectrum, Green's function, Rayleigh Integral, Velocity and far field pressure calculations, Directivity and Sound power calculation.	10	Learning various mathematical techniques to predict sound power level at a distance from the source.

Text Book

1. M. L. Munjal. Noise and Vibration Control, World Scientific Press: Singapore (2014).
2. Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens and James V. Sanders . Fundamentals of Acoustics, Wiley: New York (1999).

Other References

1. Uno Ingard. Notes on Acoustics, Firewal Media: Delhi (2010).
2. E. G. Williams. Fourier Acoustics: Sound Radiation and Near Field Acoustic Holography, Academic Press: New York (1999).
3. Acoustics of Ducts and Mufflers, 2nd Edition,M. L. Munjal, John Wiley and Sons, ISBN: 978-1-118-44312-5.(2014)

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED554	**Surface Engineering**	3	0	0	9

Course Objective
To have systematic and comprehensive understanding on various aspects related with surface engineering of metallic components.
Learning Outcomes
Upon successful completion of this course, students will able to: • Identify and design the suitable surface modification methods for different applications • Characterise the metallurgical, mechanical and tribological properties of engineered surfaces.

Module	Topics	Lecture	Learning Outcome

		Hours	
1	Fundamentals of surface engineering: definition, scope, classification, and general principles, surface dependent properties and failures, Surface and surface energy: Structure and types of interfaces.	4	Understanding of surface properties and their influences on the performance of a component.
2	Conventional surface engineering practice: Surface engineering by material removal: like etching, grinding, polishing, etc. Surface engineering by material addition: like hot dipping, Electro-plating, carburizing, Cyaniding, etc.	6	Understanding on the fundamental of basic surface modification techniques.
3	Surface engineering by energy beams: Laser assisted microstructural modification like surface melting, hardening, shocking etc., Laser assisted compositional modification like surface alloying, surface cladding, composite surfacing etc. Surface engineering by spray techniques like Flame spray, cold spray etc.,	12	Understanding of thick layer coating technology and their applications.
4	Ion beam assisted microstructure and compositional modification, Sputter deposition of thin films & coatings, PVD coating processes, Chemical vapour deposition and PECVD.	10	Understanding of thin layer coating technology and their applications.
5	Characterization of coatings and surfaces: Measurement of coatings thickness, porosity & adhesion of surface coatings, Measurement of residual stress & stability, Surface microscopy, topography and Spectroscopic analysis of modified surfaces.	7	Understanding about methods of characterization needed for evaluating the metallurgical, mechanical and tribological properties of engineered surfaces.

Text books:

1. Introduction to Surface Engineering by P. A. Dearnley, Cambridge University Press, 2017
2. Laser surface modification of alloys for corrosion and wear resistance by Chi Tat Kwok, Woodhead Publishing Limited, 2012

Reference books:

1. Surface Engineering for Corrosion and Wear Resistance by J.R. Davis, ASM international , 2001
2. ASM Hand book – Surface Engineering, ASM International, vol. 5, 9th edition, 1994
3. Surface Engineering for Wear Resistances by K.G. Budinski. Prentice Hall Publisher, 1988

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 562	**Failure Analysis and Repair**	3	0	0	9

Course Objective

The objective of the course is to equip students with various techniques of failure analysis in order to solve real life problems related to the failures and associated repair and maintenance of equipment/components.

Learning Outcomes

Upon successful completion of this course, students will:

- Be able to understand failure of components.
- Be able to modes and causes of failures.
- Be able to learn failures due to residual stresses, temperature and cracks.
- Be able to learn types of analyses of failures and remedies as well as remedies.
- Be able to solve problems related to repair components and machines in the industries by use of repair software

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction, Need for failure analysis, Classification of failures, Fundamental causes of failures, Ishikawa Diagram, Influence of types of loading (e.g. static, fatigue, shock, etc.) on nature of failures, Role of stress; Process and fabrication defects.	4	This unit will help learn basics of failures of components/machines.
2	Effect of residual stresses induced during fabrication processes, Influence of temperature and environment on failure, Crack and subsurface crack like defects and their significance in failure.	3	This unit will help students in gaining knowledge about failure due to stresses, temperature and cracks.
3	Micro mechanisms of failures; Ductile and brittle fracture, Fracture initiation and propagation, Fatigue failures, Wear related failures, High temperature failures, Low temperature failures, etc., Studies and analysis of failed surfaces	8	Understanding of various mechanisms and types of failures.
4	Identification of failures, Techniques of failure analysis, Risk analysis and Risk Matrix; RCM concept; FTA and ETA technique; FMECA, PHA and HAZOP analysis; Fracture mechanics, Prediction of failures, Residual life assessment and life extension	9	This unit will help students in learning about types of analysis of failures.
5	Typical case studies in failure analysis, Logical fault finding and its application, Inspection and safety measures, Repair techniques and economic considerations	9	This unit will help in learning case studies of failure and associated safety measures as well as repair.
6	Failure analysis for design improvement and proactive maintenance, Design for reparability, Case Studies. ALD Reliability /Thermo-Calc Software	6	This unit will help students to learn about design improvement in the machine to prevent failure and learn about associated software for repair.

Textbooks

1, Failure Analysis : Fundamentals and Applications in Mechanical Components
Otegui Jose Luis 2014 Springer International Publishing AG

Reference Book

1. Practical Engineering Failure Analysis
   Hani M. Tawancy, Anwar Ul-Hamid, Nureddin M. Abbas
   Series: Mechanical Engineering 1st Ed. 2004 CRC Press
2. ALD Reliability /Thermo-Calc-Software.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 563	**Reliability, Availability and Maintainability Engineering**	3	0	0	9

Course Objective

The objective of the course is to study the basic theory of reliability, maintainability and availability, various static and dynamic model probability models for predicting the particular natural failures in machines. To equip students with various reliability techniques in order to solve real life industrial problems and the applications of the latest Reliasoft Weibull + Software

Learning Outcomes

Upon successful completion of this course, students will:

- Be able to familiar with reliability methods and their applications.
- Be able to use the specific reliability models for probability analysis of events and failures.
- Be able to understand the applications and importance of the reliability models in industries.
- Be able to use Markov and Weibull reliability models and their applications

Module	Topics	Lecture Hours	Learning Outcome
1	Fundamentals of reliability and availability and maintainability(RAM), System concepts in RAM Engineering	5	This will familiarise with reliability analysis its importance in industries.
2	Failure distributions, Statistical analysis of failure data, Weibull analysis, Monte Carlo simulation	10	This unit will help students in understanding the various basic reliability models such static and dynamic and their application .
3	System reliability assessment, Point, mission and steady state availability, Availability assessment	5	This will help the students to understand the systems reliability when its components are arranged in series, parallel, redundant etc.
4	Reliability of repairable and non-repairable systems	4	This unit will help students to understand the methods of assessment of reliability of repairable and non-repairable systems.
5	Maintainability assessment. Design for reliability and maintainability	5	This chapters will familiarise students with reliability assessment of machines, how to ensure its maintenance under various constraints such as availability of spares, shutdown, financial resources.
6	Practical applications of RAM Engineering to systems, products and processes. Reliasoft Weibull ++ Software	10	This chapter will help the students to understand the in-depth probability of failures and reliability of the system of software by use of software.

Textbooks

1. An Introduction to Reliability and Maintainability Engineering Charles Ebeling 12 edition 2017 McGraw Hill Education
2. Jardine, A.K.S. and Tsang, A.H.C. (2013). Maintenance, Replacement, and Reliability: Theory and Applications. CRC Press, Taylor & Francis Group LLC.
3. Software Recommended for Reliability Analysis and Modelling: Reliasoft Corporation (2003). Reliasoft Weibull++ Software

References:

1. Blischke, W.R. and Murthy, D.N.P. (2003). Case Studies in Reliability and Maintenance, John Wiley & Sons.
2. Barlow, R.E. and Proschan, F. (1965). Mathematical Theory of Reliability. John Wiley, New York.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED 564	Erosion and Corrosion of Machine Components	3	0	0	9

Course Objective

- To understand theory of wear and friction.
- To study erosion and corrosion principles in machine components
- To understand reason behind real life industrial problem
- To develop research ideas to improve and design different machine components involve in power sector

Learning Outcomes

Upon successful completion of this course, students will:

- have a broad understanding about origin of friction and mechanism behind wear.
- have an understanding about different materials, their anti-erosion and corrosion properties and their application in real life problem.

- be able to write MATLAB code and use soft techniques to solve different problems.
- be able to understand reason behind erosion and corrosion related real life industrial problems and their remedy

Module	Topics	Lecture Hours	Learning Outcome
1	Basic Concepts: fundamentals of tribology, Importance of erosion and corrosion control in industrial practices.	2	Understanding the definition and history of tribology and their industrial significance are described.
2	Fundamentals of friction and wear theory: Solid–Solid Contact, Liquid-Mediated Contact, Friction of Materials, Types of Wear Mechanism, Types of Particles Present in Wear Debris, Wear of Materials. Solution of friction and wear problems and statistical estimation of surface properties using soft techniques.	5	Understanding the origins of the frictional force, and try the magnitude of the frictional interactions between metals, polymers, ceramics and other materials. To understand progressive loss of material, due to the relative motion between the surface and contacting material or substance
3	Fundamentals of abrasive Erosion Theory: Mechanism of abrasive effect produced by particles, abrasive erosion of machine components. Calculation of abrasion, analysis.	8	Understanding the hydraulic abrasion of the flow-passage components of hydraulic machines like hydro-turbines, pumps etc.
4	Erosion-resistant materials: selection of erosion-resistant materials, surface treatment against erosion damage. Organic Polymer Linings, Ceramics, Metal Protective Coating, Non-Metallic Protection Coating	8	Understanding different mechanism of erosion resistant materials and \their applications
5	Thermodynamics of corrosion. Fundamentals and application of corrosion theories, interaction of corrosion with erosion. Corrosion Control- Design improvement.	7	To estimate the temperature rise at a sliding contact that results from frictional energy dissipation.
6	Erosion and corrosion on machine components. Analysis and Numerical Simulation of Liquid-Solid Two-Phase through Hydraulic Machinery. Case studies on modelling of a machine component for studying erosion using ANSYS	9	To understand how to solve real life industrial problem related to erosion and corrosion.

Text Books:

1. Introduction to Tribology, second edition, Bharat Bhushan, Wiley

Reference Books:

1. Abrasive Erosion and Corrosion of Hydraulic Machinery, C. G. Duan, Y. Y. Karelin, Imperial College Press, 2002.
2. Guide to Wear Problems and Testing for Industry, M J Neale and M Gee, William Andrew Inc. Pub., 2001
3. Hydraulic machines guide for dealing with abrasive erosion in water. IEC 62364 Ed. 1.0, 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED565	**Nano Technology in Tribology**	3	0	0	9

To understand, characterize and modify surfaces for scientific and technological applications and the effect of nanotechnology on surface topology at the Nano scale either by surface coating or by application of nanoparticles.

Learning Outcomes

Upon successful completion of this course, students will:

- Be able to know the field of tribology in nano scale.
- Be able to know the interfacial phenomena in microstructures and related instruments.
- Be able to understand the effect of surface properties in tribology

- Be able to understand friction and wear in nano scale and measurement of surface roughness.
- Be able to learn different types of nanomaterials.
- Be able to learn the preparation and characterization of nano lubricants.
- Be able to learn friction and wear behaviour of metals and non-metals

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to nanotechnologies, Nano Tribological Phenomena, Principles and Mechanisms.	3	Introduce the students to the field of Tribology in Nano scale.
2	Significance of surfaces. Microtribology Instrumentation, Characterization of nanostructures, Low-Load Tribometers, Nanoindentation-Based Tribometers.	6	Students will learn about the fundamental understanding of interfacial phenomena in microstructures and related instruments.
3	Surface Energy and surface force: Surface tension of liquids, surface energy of solids, relation between surface force and surface energy.	4	Students will learn the effect of surface properties in tribology.
4	Nanoscale Friction, Measurement and Analysis, Friction Force Microscopy	4	Students will learn basic understanding of friction in nano scale and measurement of surface roughness, adhesion, friction, scratching, wear.
5	Nano materials: Nanoparticles, Nanotubes, Nanowires, Hybrid nanoparticles, Colloidal suspensions Nano composites, Nano sensors. Properties of nanomaterial, surface energy, wettability.	10	Students will learn different types of nanomaterials.
6	Nano fluids, lubricants and lubrication, Nano-manufacturing, nanomaterial synthesis.	6	Students will learn the preparation and characterization of nano lubricants.
7	Environmental Effects in Tribology: Metals, Ceramics, Carbon Surfaces, Solid lubricants	6	Students will learn friction and wear behaviour of metals and non-metals.

Textbooks:

1. Y.W. Chung, Micro and Nano Scale Phenomenon in Tribology, CRC Press, 2nd Ed. 2012.
2. Gabor L. Hornyak, John J. Moore, H.F. Tibbals, J. Dutta, Fundamentals of Nanotechnology, CRC Press, 1st Ed. 2008.

References:

1. Sujeet K Sinha et al., Nano-tribology and Materials in MEMS, Springer, 2013.
2. Bharat Bhushan, Nanotribology and Nanomechanics: An Introduction, Springer International Publishing, 4th Ed. 2017.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	MED566	**Simulation in Maintenance Engineering and Tribology**	3	0	0	9

Course Objective
To understand the different analytical and computational models to the field maintenance engineering and tribology.
Learning Outcomes
Upon successful completion of this course, students will: • Be able to know the computational models to the field maintenance engineering and tribology. • Be able to know the lubrication models using MATLAB.

- Be able to know the computational modelling of different Wears.
- Be able to understand simulation of failure analysis.
- Be able to learn computer simulation for different case studies related to maintenance engineering and tribology.

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to modelling and simulations in tribology and Maintenance Engineering.	2	Introduce the different analytical and computational models to the field maintenance engineering and tribology.
2	Lubrication theory, Reynolds equation, numerical methods used to solve Reynolds equation, load balance. Computer simulation for lubrication models using MATLAB.	8	Students will learn lubrication models using MATLAB.
3	Modelling of surface roughness effects. Wear models and simulation methods. Thermal effects in tribology and computer simulation. Typical results and their applicability.	9	Students will learn computational modelling of different Wears.
4	Simulation Basics related to break downs Dynamical. Finite State, and Complex Model Simulations of failures.	10	Students will learn simulation of failure analysis.
5	Probability and Statistics for Simulations and Analysis of failure events, Case study on related to break downs using MATLAB.	10	Students will learn computer simulation for different case studies related to maintenance engineering and tribology.

Textbooks

1. Y W Chung , Micro- and Nanoscale Phenomena in Tribology ,CRC, 2nd Ed.2017.
2. I.I. Kudish, M.J. Covitch, Modelling and Analytical Methods in Tribology, Chapman and Hall/CRC, 1st Ed.2010.

References

1. F.F. Ling, C.H.T. Pan ,Approaches to Modelling of Friction and Wear, springer-verlag, 1st Ed.1988.
2. K.C. Ludema, R.G. Bayer , Tribological Modelling for Mechanical Designers, ASTM, 1st Ed.1991.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MEO 588	**Risk Analysis and Safety**	3	0	0	9

Course Objective

The objective of the course is to equip students with analytical knowledge of minimization of risks in fabrication, production and operation of products and services and associated disaster and safety management.

Learning Outcomes

Upon successful completion of this course, students will:

- Be able to understand basics of risk and safety in plants and machineries.
- Be able to learn various types of risk analyses.
- Be able to learn about human safety and disaster management
- Be able to know about safety from lubricants, safety codes and risk analysis software.

Module	Topics	Lecture	Learning Outcome

		Hours	
1	Introduction, Typical Hazards, Tools for hazard identification and analysis in plants and machinery, Accident indices, Check lists	5	This unit will help learn basics of hazards and accidents
2	Preliminary Hazard Analysis (PHA), Failure mode and effects analysis (FMEA) and Failure mode, effects and criticality analysis (FMECA	10	This unit will help students in gaining knowledge about various hazard analyses.
3	Hazard and operability studies (HAZOP), Fire and explosion hazards, Dow's fire and explosion index, Hazard analysis-Fault tree analysis (FTA)	8	Understanding of specific analyses in plants and machineries.
4	Event tree analysis (ETA), Cause consequence analysis (CCA), Mathematical models for cause consequence analysis, Risk evaluation and acceptance criteria	8	This unit will help students in learning about analytical models of hazards and their evaluation.
5	Human factors in safety, safety management, Disaster management plan	4	This unit will help students in learning about human safety and disaster management
6	Safety aspects of lubricants, Safety codes, Case studies, SHE /Velocity EHS Software	4	This unit will help students to learn about safety from lubricants, safety codes and risk analysis software.

Textbooks

1. Reliability Engineering and Risk analysis - A practical guide : Mohammad Modarres, Mark P. Kaminskiy and Vasiliy Krivtsov (2016). 3rd Edition CRC Press Boca Raton
2. System Safety Engineering and Risk Assessment: A Practical Approach, Second Edition Nicholas J. Bahr20172nd Edition CRC Press.

Reference standards/software

3. ISO 45001:2018 Occupational Health And Safety Management Systems
4. Risk Assessment SHE / Risk Analysis Velocity EHS Software

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MEO 589	**Maintenance Audit**	3	0	0	9

Course Objective
The objective of the course is to impart knowledge of maintenance audit of plants and machineries to students in order to help industries solve associated expenses and improvement. .
Learning Outcomes

Upon successful completion of this course, students will:

- Be able to understand basics of maintenance audit
- Be able to learn about collection and analysis of data.
- Be able to learn about interpretation and reporting of data for improvement of maintenance activities.

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction: A Methodology for auditing the industrial maintenance function. The purpose and procedures of such auditing. An outline with examples of a full audit, a snapshot audit and a fingerprint audit.	11	This unit will help learn basics of maintenance audit and associated activities.
2	Data Collection: Information gathering strategy : Information gathering techniques: models, questionnaires, survey forms. An outline of an aide-memoire based on the audit methodology Methods of interviewing	8	This unit will help students in collection of data by different methods.
3	Data Analysis: Analysis of data, the analysis procedure, identification of problem areas, developing improved organizations and systems.	8	Understanding of analysis of data of maintenance.
4	Reporting: The report structure, the audit section, the proposal section. Discussion and analysis of actual audit reports. Audit data to identify problems, their causes and solutions.	12	This unit will help students in the interpretation and reporting of data for improvement.

Text Books

1. Maintenance Audits Handbook: Diego Galar Pascual, Uday Kumar, CRC Press; 1 edition 2016
2. Maintenance Management Audit: Hervey H. Kaiser, R S Means Co; Spiral edition 1992

References book

3. Auditing the Maintenance of Software: Vallabhaneni S Rao

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC567	**Tribological Design Lab**	0	0	3	3

List of Practical
1. Design of hydrodynamic thrust pad bearings.
2. Design of hydrodynamic journal bearings.
3. Design of hydrostatic bearing.
4. Design and Selection of rolling element bearing: Ball bearing.
5. Design and Selection of rolling element bearing: Roller bearing.
6. Design of spur gear.

7. Design of gas lubricated bearings.
8. Design of seals.
9. Design of cam and follower.
10. Design of brake and clutches.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	MEC568	**Tribology Based Maintenance Engineering Lab**	0	0	2	2

List of Practical

1. Preventive/Predictive Maintenance of Gear Hobber
2. Preventive/Predictive Maintenance of Gear Shaper
3. Preventive/Predictive Maintenance of Shaper
4. Preventive/Predictive Maintenance of Tool and Cutter Grinder
5. Preventive/Predictive Maintenance of Milling Machine
6. Preventive/Predictive Maintenance of Surface Grinder
7. Preventive/Predictive Maintenance of Drill Machine
8. Preventive/Predictive Maintenance of Wire-EDM
9. Preventive/Predictive Maintenance of Die-Sinking EDM
10. Preventive/Predictive Maintenance of CNC

3RD Semester					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
MEC 569	Thesis Unit 1	0	0	0	9
MEC 570	Thesis Unit 2	0	0	0	9
MEC571	Thesis Unit 3	0	0	0	9
MEC 572	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

4TH Semester

Course No.	Course Name	L	T	P	CH
Departmental Electives / open Elective/Dept Elective (any Two)					
MED 573	Advanced Optimization Technique	3	0	0	9
MED 574	Research Methodology and Statistics	3	0	0	9
MED 575	Advanced manufacturing systems	3	0	0	9
MEC 575	Thesis Unit 5	0	0	0	9
MEC 576	Thesis Unit 6	0	0	0	9
	Total	6	0	0	36

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MED 573	**Advanced Optimization Techniques**	3	0	0	9

Course Objective

- To understand theory of different optimization methods to solve various types of engineering problems.
- To understand physical engineering problem and to construct mathematical formulation towards solving it by selecting proper optimization techniques.
- To understand both computer programming and heuristic approaches to solve optimization problems.

Learning Outcomes

Upon successful completion of this course, students will:

- have a broad understanding formulation of engineering optimization problem, specially mechanical engg.
- have an understanding about solving the real life/ industrial /engineering/ environmental/ social problems using conventional optimization methods, that helps to take decision.
- be able to write MATLAB code for single and multivariable engineering problems.
- be able to understand and write MATLAB code for nontraditional optimization technique like GA, ANN, fuzzy logic to solve different engineering problems with single objective function and multi-objective function.

Module	Topics	Lecture Hours	Learning Outcome
1	Basic Concepts: optimization problem formulation.	2	Understanding the types and basic concept of engineering optimization problem formulation. Especially real life/ industrial /engineering/ environmental/ social problems.
2	Single variable optimization algorithms: Exhaustive search method, bounding phase method, Interval halving method, Fibonacci method, golden search method, Newton Rapshon method, bisection method, secant method. Formulation of engineering problem with single variable. Computer programming to solve the single variable problem	6	This unit discuss about different types of classical single variable optimization algorithms. Student will learn to write MATLAB code for these algorithms also.
3	Multivariable optimization algorithms: Unidirectional search, direct search methods: simplex search, gradient based methods: Cauchy's Steepest Descent method Formulation of engineering problem with multiple variable. Computer programming to solve Multivariable optimization algorithm	8	This unit discuss about different types of classical multivariable unconstrained optimization algorithms. Student will learn to write MATLAB code for these algorithms also.
4	Constrained optimization algorithms: Linear programming, nonlinear programming penalty function method, method of multipliers, sensitivity analysis, direct search for constrained minimization. Formulation of engineering problem with constrained multiple variable. Related computer Programming.	6	Student will learn constrained optimization algorithms and their computer programming.
5	Nontraditional optimization: Introduction to Genetic algorithm (GA), Artificial Neural Network (ANN), fuzzy logic etc with single objective function. Computer programming, other evolutionary algorithms. Formulation of engineering problem and solve with Nontraditional optimization.	9	This unit demonstrates basics of Nontraditional optimization techniques. Use of Nontraditional optimization like GA, ANN, fuzzy logic with single objective function to solve different engineering problem.
6	Multi-Objective Optimization: Introduction to linear and nonlinear multi-objective problems, Use of Evolutionary Computations to solve multi objective optimization with computer programming in MATLAB	8	This unit demonstrates Nontraditional optimization techniques to solve different engineering problem with multi objective function.

Text Books:

1. Deb, K. Optimization for engineering design: algorithms and examples. Prentice Hall of India, New Delhi. 2nd

Edition 2012

Reference Books:

1. K.Deb, Multiobjective optimization using Evolutionary Algorithm. Wiley. 1st Edition, 2001.
2. Rao, S.S. Engineering Optimization: Theory and Practice. Wiley. 3rd Edition, 2014
3. Ravindran, A., Ragsdell, K. M., Reklaitis, G. V. Engineering Optimization: Methods and Applications, Willey, 2nd Edition, 2013

Rardin, Ronald L. Optimization in operations research. Prentice Hall.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MED 574	**Research Methodology and Statistics**	3	0	0	9

Objective

To illustrate students a) the basic concepts of research, b) how a scientific research problem has to be formulated and tackled and c) important statistical tools necessary to analyze the collected data for a meaningful research outcome.

Learning Outcomes

On successful completion of the course, the students will

- Learn various types of research process, methodologies to identify, design and execute a research problem based on scientific and statistical tools;
- Learn various types of sample design techniques and its classification, characteristics of a good sample design and how to select a sampling procedure for data collection;
- Learn various types of measurement scales, sources of error in measurement and technique of developing measurement tools to evaluate the collected data;
- Learn various methods of data collection and the reliability and validity of the collected data;
- Learn various ways to prepare and present report for dissemination of research outcome;
- Learn various statistical tools necessary for designing a sample, analyzing the data and making scientific conclusion(s) out of the collected data to arrive at a research outcome.

Module	Topics to be Covered	Lecture Hours	Learning outcomes
1	Research Process, Types of Research, Problem identification, Hypotheses formulation	5	Basic ideas on research processes, Definition of various types of research, Knowledge on what constitute a research and how to identify a research problem, Knowledge on the formulation of hypothesis for research
2	Research Design: General Designs of Research, Randomized and Correlated Groups Design	5	Meaning of research design, Ideas on the need for research design, Knowledge on the features of a good research problem design, Important concepts relating to research design, Ideas on different research design methodologies, Ideas on the basic principles of experimental designs.
3	Sampling Design, Measurement and Scaling, Methods of Data Collection, Reliability and Validity	5	Ideas on the Implications of a Sample Design and its classification, Knowledge on the criteria of selecting a sampling procedure and characteristics of a good sample design, Ideas on measurement scales and sources of error in measurement,

			Knowledge on technique of developing measurement tools, Ideas on the meaning of scaling and important scaling techniques, Ideas on the methods of data collection and the reliability and validity of the collected data.
4	Data Presentation and Report Preparation, Introduction to Qualitative and Quantitative Research Methods	3	Ideas on Data presentation and report preparation techniques, Sensitizing the students on the very important issues of plagiarism, Preliminary ideas on the qualitative and quantitative research methodologies and their mutual difference.
5	Frequency Distribution, Presentation of Data, Measures of Central Tendency, Measures of Dispersion, Skewness	3	Ideas and knowledge on frequency distribution, cumulative frequency distribution, constructing histograms, Knowledge on the measures of central tendency (Mean, Median and Mode), Various measures of dispersion of the data.
6	Probability Distributions, Discrete and continuous random variable, Binomial, Poisson, Normal and Standard Normal distributions	6	Learn about Experiment, Outcomes, and Sample Space, Calculation of Probability, Ideas on Marginal and Conditional Probabilities, Learn about Mutually Exclusive, Independent and Complementary Events, Learn about Bay's Theorem, Learn about discrete and continuous random variables and how to calculate their mean and standard deviation, Learn about Binomial, Poisson, Normal and Standard Normal distributions.
7	Sampling and Estimation, Sampling Distribution, Estimation of the mean and proportion, Hypothesis tests about the mean and proportion of a population, t-test and z-test, Estimation and hypothesis testing about two different populations.	6	Learn about sampling and estimation methods, hypothesis testing regarding the properties of the population from the sample statistics (sample mean and variance), Learn about Student's t-distribution and z-distribution and t-test and z-tests, Knowledge on estimation and hypothesis testing about two different populations
8	Hypotheses testing: □□ test, Analysis of Variance, Correlation and Regression analysis.	6	Learn about the Chi-Square distribution, Goodness-of-Fit test, Learn about making contingency tables, Learn about testing independence or homogeneity of populations, Learn to infer about the population variance, F-Distribution and one-way ANOVA, Learn about simple linear regression models and analysis.

Textbook:

1. 'Research Methodology - Methods and Techniques' C R Kothari and Gaurav Garg New Age International (P) Limited Publishers 4rth Edition, 2019 New Delhi
2. 'Applied Statistics and Probability for Engineers' D C. Montgomery and George C. Runger 6 th Edition, 2016

References:

1. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar, SAGE Publications Ltd; Fifth edition 2018.
2. Introductory Statistics, Prem S. Mann, 7th Edition, John Wiley and Sons Inc., 2010, Danvers, MA.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	MED 587	**Advanced Manufacturing Systems**	3	0	0	9

Course Objective

The course will provide the advances in manufacturing system and their implementation issues.

Learning Outcomes

On successful completion of the course, the students will

- Able to design different plant layouts
- Able to form cell for cellular manufacturing system
- Understand the concept of modern manufacturing systems

Module	Topics	Lecture Hours	Learning Outcome
1	Introduction to Manufacturing systems, Classification of Manufacturing systems. Analysis of single station, assembly line and job shop problems.	6	Understanding the various types of manufacturing systems.
2	Group Technology: Concepts, merits, demerits and applications, Opitz classification system and production flow analysis. Cellular Manufacturing: Principle of cell formations, applications, different methods of cell formations. Case Studies.	12	Appreciating group Technology and Cellular Manufacturing in the perspective of modern day manufacturing processes and their role in the enhancement of the productivities.
3	FMS: Concepts of FMS, components, FMS layouts. Analysis of Flexible Manufacturing systems., CIM: Concepts, applications	11	Understanding the concept of Flexible Manufacturing Process and the application of Computer Integrated Manufacturing System
4	Lean Manufacturing: concepts, implementation methodology, case studies. Agile Manufacturing: Definition, agility, method of implementation, relationship between lean and agile manufacturing. Case Studies.	10	Understanding the concept of Lean and Agile Manufacturing and their applications in a competitive environment with special reference to the case studies.

Text books:

1. Automation, Production Systems, and Computer-integrated Manufacturing, M. P. Groover, Pearson Education, 4th Edition, 2016

Reference books:

1. Materials & processes in Manufacturing, Degarmo, J. T. Black.
2. Lean Manufacturing System & Cell Design, J. T. Black.
3. Cellular Manufacturing Systems Design, planning and control by Singh, N., Rajamani, Divakar