Syllabus for Comprehensive Exam for PhD Programme in Mechanical Engineering

Manufacturing & Industrial Engineering Section

Module 1: **[25 Marks]**

pattern allowances, cooling and solidification, Elements of gating system, design of gating system, Design of risers – Modulus –Caine's and shape factor methods.

Different welding processes: Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW), Gas Tungsten Arc Welding (GTAW/TIG), Gas Metal Arc Welding (GMAW), Electro-slag and Electro-gas welding, Resistance welding, Solid-state welding processes, Ultrasonic, Electron beam welding, Laser welding, Plasma arc welding, Thermit welding, Design of weldments, Joint design.

Module 2: **[25 Marks]**

Metal cutting principles, classification and mechanism of chip formation, types of chips, chip breakers, chip thickness ratio, shear plane, shear angle, shear strain, shear strain rate, shear angle relationships, velocity relationships, force analysis in orthogonal cutting; force analysis in drilling and milling process, tool life criteria for different tool materials, Design of cutting tools, Selection of carbide cutting tools, Die-design fundamentals; Design of Blanking and Piercing die, Progressive die, Strip-layout, Deep drawing die.

Material removal mechanism, parametric analysis, tool design, limitations, and applications for Ultra Sonic Machining, Abrasive Jet Machining (AJM), Abrasive Water Jet Machining (AWJM) processes, Electrochemical & Chemical Processes, Electrical Discharge Machining (EDM), Laser Beam Machining (LBM), Electron Beam Machining (EBM)

Module 3: **[25 Marks]**

Theory of Elasticity and Plasticity, Stress tensor, stress transformations, strain transformations, octahedral strains, finite deformations, Mohr's circle, Hooke's law for isotropic and homogeneous materials, plane stress and plane strain. Theory of plasticity, yield criteria for metals, Von- Mises' yield criterion, Tresca's yield criterion, models of material behaviour, LevyMises (flow rule) and Prandtl-Reuss stress strain relations. Slip Line Field Theory, Henkey's theorems, hodograph, simplest slip line fields. Metal forming processes: Rolling – rolling pressure, driving torque and power, power loss, Wire-drawing - drawing force and power, maximum allowable reduction, Extrusion - work load, Forging –maximum forging force, Deep-drawing - estimation of the drawing force, Bending - work load, spring back, Punching and blanking – deformation model and fracture analysis, determination of working force, Friction and Lubrication in metal forming.

Module 4: **[25 Marks]**

Rapid Prototyping and Tooling, Stereo Lithography Systems, Laser Sintering Systems, Fusion Deposition Modelling, Laminated Object Manufacturing, Laser Engineering Net Shaping (LENS)

Computer aided manufacturing: NC/CNC system, Programming formats, Part programming for lathe and machining centres. CNC tooling, Group technology - production flow analysis, Parts classification and coding

Module 5: **[25 Marks]**

Smart materials exhibiting ferroelectric, piezoelectric, optoelectric, semiconducting behavior, lasers and optical fibers, photoconductivity and superconductivity, nanomaterials , , biomaterials, superalloys, shape memory alloys Metallography (Optical TEM, SEM), X Ray Diffraction, Mechanical Properties, Thermal analysis.

Service Performance, Failure, Corrosion-types(Atmospheric, Pitting, Stress Corrosion),Control and Prevention, Protective Coatings, Performance of Metals and Ceramics at High Temperature.

Polymer Based Composite Materials: Reinforcement Forms and matrix description- interface-statistical distribution of fiber strength– shear strength of interfacial bond, fiber pull out – mechanical testing of composite and constituents

Module 6: **[25 Marks]**

Demand forecasting using qualitative and quantitative methods, Errors in forecasting. Design of layout, Mathematical model for facility location and layout, Quantitative methods for capacity planning, Methods for aggregate planning, Material Requirement Planning and ERP, Lot sizing Technique and Extension of MRP, Scheduling and Shop floor planning and control; order sequencing rules, Mathematical models of job sequencing. Multi item Deterministic Model, Dynamic and Fluctuating Models, Deterministic Model with price breaks and Probabilistic inventory models.

Statistical quality control and acceptance sampling, Total Quality Management and its techniques, Five S, kaizen, Quality Circles, Quality Function Deployment (QFD), Poka Yoke, Total Productive Maintenance (TPM).

Books:

1. A. Ghosh and A. K. Malik, Manufacturing Science, Affiliated East West Press Pvt. Ltd., New Delhi, 2008
2. P. L. Jain, Principles of Foundry Technology, 5th edition, TMH Publications, 2009
3. R. S. Parmar, Welding Processes and Technology, 3 rd Edition, Khanna Publishers, New Delhi, 2011
4. G. Boothroyd and W. A. Knight, Fundamentals of machining and machine tools, Taylor and Francis, 3rd Edition, 2006
5. Cyril Donaldson, George H. Lecain and V. C. Goold, Tool design, 4th edition, TataMcGraw Hills, 2010
6. V. K. Jain, Advanced Machining processes, Allied publishers, New Delhi, 2008
7. Stephan Timoshenko, and J. N. Goodier, Theory of Elasticity, McGraw Hill, 2010
8. Chua Chee Kai, Leong Kah Fai, Lim Chu -Sing, Rapid Prototyping: Principles and Applications, 2 nd edition, World Scientific, 2003
9. P. Radhakrishnan, S. Subramanyan, and V. Raju, CAD/CAM/CIM, 3rd edition, New age International publishers, 2011

10. R. E Small Man, A.H.W Ngan, Physical Metallurgy and Advanced Materials, seventh edition,Butterworth-Heinemann, 2007
11. Robert M Jones, Mechanics of composite material, Taylor & Francis 2nd edition, Newyork, Indian Print 2010
12. Everett E. Adam, Ronald J. Ebert, Production and Operations Management, 5th edition, Prentice Hall of India, New Delhi, 2012
13. Amitra Amitava, Fundamentals of Quality Control and Improvement, 2nd Ed., Prentice Hall of India, 2011

Thermal and Fluid Section

Module 1: Thermodynamics **[25 marks]**

First law and Second law and analysis for control volume; Irreversibility and availability; Rankine cycle with superheat, reheat and regeneration, Super-critical and ultra-super-critical Rankine cycle; Gas power cycles, Effect of reheat, regeneration and intercooling, Combined gas and vapor power cycles; Vapor compression refrigeration cycles and its analysis; Otto, diesel and dual cycle for internal combustion engines; Commonly used refrigerants and their properties; Pschyrometric principles; Application of mass and energy balances to air-conditioning systems; Wet and dry-bulb temperatures; Pschyrometric chart; Air conditioning processes.

Module -2: Heat Transfer **[25 marks]**

Derivation of Heat Balance Equation (for low speed flows) in Cartesian Coordinates- Generalization for cylindrical & spherical coordinates- Types of boundary conditions; one dimensional steady conduction solutions in Cartesian, cylindrical & spherical geometries- steady/ unsteady conduction solutions by separation of variables technique; Velocity and Thermal Boundary layers; Thermally developed laminar flow solutions, Nusselt number for constant heat flux and constant wall temperature; Black and gray body radiation- radiation in enclosures, Intensity and Radiative transport equation for bulk radiation.

Module 3: Fluid Mechanics **[25 marks]**

Concept of continuum; Kinematics of fluid motion; Eulerian and Lagrangian Approach; Reynolds transport theorem; Navier-Stokes equation; Analytical solutions to simple flows; Couette Flow; Poiseuille flow; Stream function and velocity potential; Concept of lift and drag; Concept of boundary layer; Boundary layer flow over a flat plate and with non-zero pressure gradient; Flow separation and drag; Free shear flow; Characteristics of turbulent flows; Reynolds Averaged Navier Stokes (RANS) equations; Compressible flow; Normal shocks.

Module 4: Measurements in Thermal Engineering **[25 marks]**

Primary and derived quantities, intrusive and non-intrusive methods; Types of errors, uncertainty analysis, propagation of uncertainty; Statistical analysis of experimental data- normal error distributions; Chi-square test of goodness of fit, method of least squares (regression analysis, correlation coefficient), multivariable regression, graphical analysis and curve fitting; System response- first and second order systems and analysis; Thermoelectric and resistance thermometry, pyrometry, liquid in glass Measurement of pressure; Measurement of volume flow rate; Measurement of velocity; velocity measurement based on thermal effect, Doppler velocimeter.

Module 5: Conventional Energy Systems [25 marks]

Solid, liquid and gaseous fuels and their properties; HCV and LCV; Combustion reactions; Stoichiometry, Adiabatic flame temperature, bond energy and heat of formation, dissociation; Cogeneration and Combined Cycle Power Generation; Modern thermal power plants; Once-through boiler in supercritical power plants; Binary cycle power systems; Steam nozzles and Steam Turbines; Gas Turbines; Fans, Compressors and Blowers; Hydraulic Turbines; Centrifugal and Axial Flow Pumps.

Module 6: Renewable and Sustainable Energy [25 marks]

Solar Thermal Systems and Performance Testing of Various Solar Thermal Systems: Design of PV systems; Solar Photovoltaic-Thermal Systems; Wind Energy Conversion Systems and their Performance analysis; Biomass to Bio-energy; Biogas Plants, Gasification Systems; Plasma Gasification, Trans-esterification Process and Biodiesel; Energy Storage devices; Battery–Storage Technology; Thermal Energy Storage; Energy Policy and Act; Technology Management; Innovation and IPR; Environmental Impact Assessment.

Books:

1: Yunus A. Cengel & Michael a. Boles, "Thermodynamics" 4 th Ed., Tata Mc Graw Hill, New Delhi, 2004.

2: J.P.Holamn, "Heat Transfer", McGraw Hill Book. Co., 2002

3: Yunus A. Cengel, John. M. Cimbala, Fluid Mechanics: Fundamentals and Applications (4th edition, SIE), 2019.

4: Doeblin, E.O., "Measurement System–Application and Design–McGraw Hill International Ed., 1990.

5: Twidell, J.W., and Weir, A.D., "Renewable Energy Resources", ELBS, 2000.

Design and Dynamics Section

Module: 1 Mechanics of Materials [25 Marks]

Stresses and Strains:
Types of Stresses, Hook's Law, Lateral Strain, Poisson's Ratio, Varying Cross Sections, Composite Sections, Relation Between Modulus of Elasticity, Modulus of Rigidity and Bulk Modulus, Thermal Stresses.

Shear Force and Bending Moment Diagram:

Types of Supports, Types of Loads, Shear Force, Bending Moment, Sign Conventions, Overhanging Beams, Point of Contra-flexure, Varying Loads, Relation Between SF and BM.

Stresses in Beams:
Moment of Resistance, Beam of Uniform Strength, Flinched Beams, Shear Stress Concept, Derivation of Shear Stress, Shear Stress Variation in Various Sections.

Principal Stresses and Torsion:
Principal Plane, Principal Stress, Tangential and Normal Stress, Derivation of Major And Minor, Principal Stresses for Different Cases, Mohr's Circle, Graphical Method, Power Transmitted by Shaft, Composite Shafts, Strain Energy.

Column and Strut:
Euler's Theory for Columns, Different End Conditions, Rankine's Formula, Limitations of Euler's Theory.

Module: 2 Theory of Machine [25 Marks]

Velocity and Acceleration Analysis:

Vectors, Displacement of a Rigid Body, Relative Displacement, Relative Velocity Method (Graphical and Analytical), Instantaneous Axes of Motion, Velocity Analysis by Instantaneous Centers, Coriolis Component of Acceleration, Examples of Acceleration Analysis, Acceleration Diagrams, Kinematic Analysis of Mechanisms.

Belts, Ropes and Chains:
Open and Crossed Belt Drives, Velocity Ratio, Slip, Materials for Belt and Ropes, Law of Belting, Length of Belt, Ratio of Friction Tensions, Power Transmitted, Centrifugal Effect on Belts, Maximum Power Transmitted By a Belt, Initial Tension, Creep, Chains, Chain Length, Angular Speed Ratio.

Gears and Gear Trains:
Law of Gearing, Velocity of Sliding, Forms of Teeth, Cycloidal Profile Teeth, Involute Profile Teeth, Arc of Contact, Number of Pairs of Teeth in Contact, Interference in Involute Gears, Minimum Number of Teeth, Interference between Rack and Pinion, Cams and Followers.

Module:3 Dynamics of Machine [25 Marks]

Dynamic Force Analysis:
Static Equilibrium, Free Body Diagrams, Analysis of Mechanisms, Spur Gears, Worm Gears. Inertia Forces, Analysis of a Floating Link, Rotation, Method of Virtual Work, Dynamic Analysis of Four-Link Mechanism, Combined Static and Inertia Force Analysis of Different Mechanisms, Turning – Moment Diagrams, Fluctuation of Energy, Flywheels.

Balancing and Governors:
Static Balancing, Dynamic Balancing of Several Masses in Different Planes, Balancing of Inline Engines, V-Engines, Radial Engines, Balancing Machines, Sensitiveness of Governor, Hunting, Isochronisms, Stability, Effort and Power of a Governor.

Gyroscope:
Angular Velocity, Angular Acceleration, Gyroscopic Couple, Gyroscopic Effect on Naval Ships, Stability of an Automobile, Stability of a Two-Wheel Vehicle.

Module: 4 Mechanical Vibrations [25 Marks]

Fundamental of Vibration:
SHM, Beats Phenomenon, Complex Method of Representing Harmonic Vibrations, Un-damped Free Vibrations of Single Degree of Freedom System.

Free and Forced Vibration of Single Degree Freedom Systems:
Forced Vibration, Vibration Isolation and Transmissibility, Measuring Instruments, Displacement, Velocity, Acceleration and Frequency Measuring Instruments, Whirling and Critical Speed of Shafts.

Module: 5 Design of Machine Elements [25 Marks]

Design Analysis:

Types of Loads and Stresses, Factor of Safety Types Of Failure, Theories of Failure, Fatigue Failure Analysis, Soderberg And Goodman Methods, Estimation of Life of A Component, Wear Failure, Creep Failure, Failure Criteria for Designing Composites.

Machine Components:
Parts Subjected To Tension, Compression, Shear, Bending and Torsion – Such as Tie Rods, Push Rods, Levers, Axels Etc. Parts Subjected To Combined Loads, Design of Helical Compression and Extension Springs, Leaf Springs, Cotter and Knuckle Joints, Riveted and Welded Joints.

Screwed and Threaded Fasteners:
Types of Screw Threads, Indian Standard Proportions, Design of Power Screws, Threaded Fastness Types of Bolts and Connections, Stresses And Preloading of Bolts. Flanged Connections Bolted Connections.

Shafts and Simple Machines:
Design of Shafts, Deflection of Shafts, Critical Speed, Design of Keys, Design of Rigid and Flexible Couplings, Screw Jack.

Module: 6 Design of Machine Components [25 Marks]

Design of Power Transmission Elements:
Design of Belt Drives, Selection of Flat and V-Belts, Design of Pulleys and Flywheels, Design of Gear Drives–Spur, Helical, Bevel and Worm Gear Drives, Design of Gear Boxes.

Design of Brakes and Clutches:
Types of Clutches, Design of Single & Multiple Plate Clutches, Cone Clutch and Centrifugal Clutch, Design of Block Brake, Pivoted Shoe Brake, Internal Shoe Brake, Simple and Differential Band Brake.

Design of Bearings:
Design of Hydrodynamic Journal Bearings, Somerfield Number and Estimation of Minimum Film Thickness, Temperature Rise, Flow Quantity etc., Rolling Contact Bearings, Classification and Selection, Factors Affecting Bearing Life, Bearing Assembly and Lubrication.

Introduction to Pressure Vessels:

Thin and Thick Cylinder, Classification of Pressure Vessels, Loads, Stresses and Types of Failures.

Books:

1. Bhandari V. B., "Design of Machine Elements", 3rd Edition, Tata McGraw Hill, 2012.
2. Budynas R. G. and Nisbett R. K., "Shigley's Mechanical Engineering Design", 9th Edition, McGraw Hill, 2011.
3. Bevan T., "Theory of Machines", CBS Publishers, New Delhi, 1984.
4. Rattan S. S., "Theory of Machines", Tata McGraw Hill, 2005.
5. Dicker J. J., Pennock, G. R. and Shigley J. E., "Theory of Machines and Mechanisms", Oxford University Press, 2003.
6. Ghosh A. and Mallik A. K., "Theory of Mechanisms and Machines", 3rd Edition, East West Press Pvt. Ltd., 2009.
7. Thomson W. T., Dahleh M. D. and Padmanabhan C. "Theory of Vibration with Applications", 5th Edition, Pearson Education, 2007.
8. Beer F. P. and Jhonston (Jr.) E. R., "Mechanics of Materials", Tata McGraw Hill, 2005.
9. Rao, S. S., "Mechanical Vibrations", 5th Edition, Prentice Hall, New York, 2011.
10. Gere J. M. and Goodno B. J., "Mechanics of Materials", 8th Edition, Cengage Learning, UK, 2013.