Department of Mechanical Engineering

Syllabus for Written section of PhD Comprehensive Examination (2022 Admission onwards)

Core Section:

Module 1: Mathematics

Limit, continuity, differentiability, mean value theorems, higher order and partial derivatives, sequences and series, convergence, multiple integrals, vector field: divergence and curl, integral theorems, Linear algebra: solution of a system of linear equations, vector spaces, rank and determinant, eigenvalue problems, Ordinary Differential Equations (ODE): solution of first order ODE, solution of second order non-homogeneous ODE with constant coefficients, Probability distributions and random variables, statistics: population and sampling, tests of hypothesis, analysis of variance, curve fitting, Partial differential equations (PDE), First order and second order PDEs, complex numbers and functions.

Module 2: Basic Mechanical Engineering

Engineering Mechanics - Equilibrium of rigid bodies in two and three dimensions, Free-body diagrams.

Materials and Manufacturing - Mechanical properties of Engineering materials; Stress-Strain diagram of mild steel, Tensile testing, Classifications of cast iron and steel, Fundamentals of Machining and Machine tools: Tool nomenclature and Tool life equation.

Fluid properties - viscosity, surface tension, density, Fluid pressure, Types of fluids, Types of flows, Bernoulli's principle, Classification of Pumps and Turbines.

Thermodynamics - State, Path and Point functions, Process and Cycle, Work and Heat, First and Second law of thermodynamics, Carnot cycle, Basic modes of heat transfer.

Module 3: Research Methodology

Understanding the language of research: Concepts, constructs, operational definitions, variables, propositions, hypotheses, theories, and models - Research process- Literature review -Types of research Problem identification and formulation - Research question and Research hypothesis, Methods of data collection, Types of data- Primary data- Scales of measurement.

Processing and analysis of data: Sampling- Steps and characteristics of sampling design, Sampling: Sampling Frame, Sample size and its determination, Types of sampling distributions - Sampling error - Statistics in research, Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Measures of relationship- Correlation and regression- Simple regression analysis- Multiple regression -Hypothesis Testing -parametric and non-parametric tests- Analysis of single factor experiments.

Reporting and presenting research: Written and oral communications - Format of dissertations, research reports, and research papers Paper title and keywords Writing an abstract Writing the different sections of a paper - Revising a paper - Responding to peer reviews - Reviewing research papers - Plagiarism - Conference and poster presentations - Language aspects of report writing - Verb, tense and voice in scientific writing - Errors in grammar - Sentence and paragraph constructions -Paraphrasing – Measures of research impact.

Intellectual property rights: Copyright - Patents - The codes of ethics.

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Specialization Section*:

Module 1: Industrial Engineering and Management

Decision modelling: Formulation and solution of linear programming problems, primal-dual relationships, sensitivity analysis, formulation and solution of integer programming problems, Network models and solutions, unconstrained and constrained optimization.

Statistics: Numerical description of data, Discrete and continuous probability distributions, confidence interval estimation for the mean and proportion, hypothesis testing for single populations about a population mean, Chi-Square goodness of fit test.

Supply chain management: Supply chain drivers, performance measures, models for facility location and capacity allocation, vehicle routing in transportation.

Inventory control: Single period inventory models, periodic review and continuous review policies, deterministic and probabilistic inventory models, selective control of inventories.

Manufacturing planning and control: Demand forecasting, aggregate production planning, master production scheduling, material requirements planning, flow shop scheduling, job shop scheduling.

Work systems design: Method study, time study, productivity measurement. Introduction to Human factors and Ergonomics – Nature of man-machine systems and characteristics, human information processing model, Engineering anthropometry and work-space design, Principles of work design

Statistical quality control: Control charts for variables and attributes, process capability, acceptance sampling.

Marketing management: Consumer behavior, marketing research, new product development, market segmentation, pricing.

Module 2: Mechanics and Machine Design

Engineering Mechanics:

Statics: Free-body diagrams, Centroids, Centre of gravity and moment of inertia of areas and masses- Friction- Laws of Coulomb friction, block friction.

Dynamics: Particle kinematics: velocity and acceleration calculations in rectangular and polar coordinates, Particle dynamics: Newton's laws, energy and momentum methods, moment-of-momentum equation for a particle.

Solid Mechanics:

Definition of stress, deformation and strain, Hooke's Law relations for isotropic materials, Analysis of normal and shear stresses, Thermal strains, Solution of statically indeterminate problems.

Torsion of circular shafts- formula and its underlying assumption

Bending of beams (Pure Bending), Basic assumptions, Euler-Bernoulli beam theory and its applications,

Transformation of stresses and strains for two dimensional problems, Mohr's circle for stress and strains for two dimensional problems.

Mechanics of Machinery and Vibrations:

Kinematics of mechanisms, degrees of freedom, position, displacement, velocity and acceleration analysis, Kinematic synthesis, static and dynamic force analysis of mechanisms.

Vibration analysis of single degree freedom systems: un-damped and damped systems, free and forced vibration

Machine Design:

Selection of materials, statistical considerations in design, stress concentration, Theories of failure, design for impact and fatigue loads- Design of various types of joints like threaded joints, welded joints, Design of machine elements like springs, power shafting, clutches, brakes, design of gears.

Module 3: Manufacturing Technology

Machining Science: Mechanics of metal cutting, Merchant circle, cutting tool geometries, tool materials, tool wear, tool life and economics of machining, micromachining, additive manufacturing.

Metrology: Limits, fits and tolerances, Computation of Measurement Uncertainty according to GUM, Geometric Dimensioning and Tolerancing, Coordinate Measuring Machines, Surface Finish Measurement.

Modern machining processes: Abrasive Jet machining, Ultrasonic machining, Chemical and electrochemical machining, electro-discharge machining, wire EDM, Electron beam machining, Laser beam machining.

Machine Tool Design and Computer Numerical Control: Design of Metal cutting machine tools, kinematics, layouts. CNC Machine tools - Design, mechatronic elements, CNC programming

Module 4: Materials Science

Mechanical behavior of materials: Plastic deformation by slip and twinning, Slip systems, dislocation interactions, strengthening mechanisms. Fracture: Brittle and ductile fracture, Fatigue, creep and stress rupture.

Phase transformation: Driving force, Homogeneous and heterogeneous nucleation, Ferrous and non-ferrous metallurgy - Iron carbon diagrams, heat treatment of steels, Cast irons- types, effect of elements, defects.

Ceramics: Types of ceramics, Common ceramic crystal structures, structural rules, Production process for ceramics, Sintering process, Testing and property evaluation of ceramics

Composite materials: Classification of composites based on types of matrix, reinforcement, Strengthening mechanisms, Analysis of Continuous and discontinuous fiber and laminated Composites

Metal casting and joining: Solidification, casting processes, design of castings, inspection. Joining processes - Arc welding, laser beam, ultrasonic, etc., Adhesive bonding, Heat affected Zone.

Module 5: Thermo-fluid and Energy

Fluid mechanics and machines: Fluid Statics and kinematics; Fluid dynamics: Continuity and Momentum equations, Euler's equation, Bernoulli's equation. Prandtl's boundary layer, Integral momentum equation. Plane Couette and Poiseuille flows; Classification and performance analysis of hydraulic turbines and pumps.

Thermodynamics: Energy interactions; First law and second law of thermodynamics applied to non-flow and flow processes; Pure substances; Entropy principle; Exergy balance; Thermodynamic property relations; Non-reactive gas mixtures, Gibbs phase rule; Onsager's reciprocity theorem.

Heat Transfer: Modes of heat transfer, Heat conduction equation in different geometries; boundary conditions; Convection heat transfer: Energy equation for steady, laminar, forced/natural convection heat transfer over flat plate, tubes and ducts. Heat exchangers; Thermal radiation: concepts of black and grey bodies, diffuse and specular surfaces. Radiant energy exchange between two surfaces, radiation shape factor.

Thermal Power Cycles: Analysis of gas power cycles and actual cycles. Four stroke and Two stroke engines, valve timing and port timing diagrams; Combustion in IC engines: Stages of combustion, ignition lag, flame propagation, knocking in SI and CI engines, pre-ignition, ignition delay. Properties of steam, Rankine cycle: inter-cooling, reheat and regeneration.

* Note: The syllabus for the Specialization Module for candidates with an interdisciplinary research area or UG/PG background may be framed separately by the guide and PhD Coordinators and forwarded to the Doctoral Committee for approval.

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