Institute of Infrastructure, Technology, Research And Management (IITRAM)

Syllabus for Written Test
PhD Admission Spring Semester (2022-23)

Part-I
Research Methodology -Common for all Engineering disciplines (e.g: Civil, Electrical, Computer Science, Mechanical and Aero Space Engg.)

- **Introduction to engineering research**: Definition, characteristics and types, basic research terminology, qualities of a researcher, research methods vs methodology, overview of engineering research methods, role of Information and Communication Technology (ICT) in research, research ethics, intellectual property rights and scholarly publishing.

- **Research formulation:** Defining and formulating the research problem, selecting the problem, necessity of defining the problem, literature survey significance in defining a problem, various sources, critical review, identifying gap areas from literature review and research databases, development of working hypothesis.

- **Research design and data analysis:** Research design basic principles, need of research design, features of good design, important concepts relating to research design, observation and facts, laws and theories, method validation, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization and interpretation.

- **Technical writing:** Types (thesis, report, journal papers etc.), qualities, structure and components of good technical document, use of software tools (Word processing, latex, etc.), illustrations and tables, bibliography, referencing and footnotes. Oral presentation planning, software tools, creating and making effective presentation, use of visual aids, importance of effective communication.

Part-II

DEPARTMENT OF CIVIL ENGINEERING

Candidate shall attempt any ONE SECTION of choice.

Section A

1. Structural Engineering

- Fundamentals of Engineering mechanics, solid mechanics, structural analysis, design of RCC structures, design of steel structures, structural dynamics, construction materials and management, Earthquake Engineering.

Section B

2. Water Resources Engineering

- Fluid Mechanics, Hydrology: Precipitation, Stream flow measurements, Hydrographs, Flood and Flood Routing, Open Channel Hydraulics: Introduction, Uniform Flow, Energy-Depth Relationships, Gradually Varied Flow-Theory & Computations, Rapidly Varied Flow-Hydraulic Jump, Unsteady Flows.

Section C

3. Geotechnical Engineering

- Index and engineering properties of soils, slope stability, subsurface exploration, shallow foundations, deep foundations, earth retaining structures, ground improvement techniques.

Section D

4. Transportation Engineering

- Traffic Engineering – Fundamental parameters of Traffic Flow : Macroscopic and Microscopic Time space diagram : one vehicle & multiple vehicle Fundamental flow diagram : Speed Vs density; flow Vs density; speed Vs flow, Flow Models
- Highway Geometric Design – Horizontal and Vertical Alignment, Sight Distance, etc.
- Pavement Engineering – Pavement design, Pavement materials, Pavement maintenance.

Section E

5. Environmental Engineering

- Water treatment: Sources of water, Quality and quantity of water, Drinking water standards, water requirements, water chemistry, basic unit operations and processes for water treatment.
- Wastewater treatment: Primary, secondary and tertiary treatment of wastewater, sludge disposal, effluent discharge standards.
- Air Pollution: Types of pollutants, their sources and impacts, Air quality standards, air pollution meteorology.

Part-II

DEPARTMENT OF ELECTRICAL AND COMPUTER SCIENCE ENGINEERING

Electrical Engineering (A):

- **Engineering Mathematics:** Linear Algebra: Matrix Algebra, Systems of linear equations, Eigenvalues, Eigenvectors Calculus: Mean value theorems, Theorems of integral calculus, Evaluation of definite and improper integrals, Partial Derivatives, Maxima and minima, Multiple integrals, Fourier series, Vector identities, Directional derivatives, Line integral, Surface integral, Volume integral, Stokes's theorem, Gauss's theorem, Divergence theorem, Green's theorem. Differential equations: First order equations (linear and nonlinear), Higher order linear differential equations with constant coefficients, Method of variation of parameters, Cauchy's equation, Euler's equation, Initial and boundary value problems, Partial Differential Equations, Method of separation of variables. Complex variables: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, Taylor series, Laurent series, Residue theorem, Solution integrals. Probability and Statistics: Sampling theorems, Conditional probability, Mean, Median, Mode, Standard Deviation, Random variables, Discrete and Continuous distributions, Poisson distribution, Normal distribution, Binomial distribution, Correlation analysis, Regression analysis.
- **Electric circuits:** Network elements, Ideal voltage and current sources, dependent sources, R, L, C, M elements; Network solution methods: KCL, KVL, Node and Mesh analysis; Network Theorems: Thevenin's, Norton's, Superposition and Maximum Power Transfer theorem; Transient response of dc and ac networks, sinusoidal steady-state analysis, resonance, two port networks, balanced three phase circuits, star-delta transformation, complex power and power factor in ac circuits.
- **Electromagnetic Fields**: Coulomb's Law, Electric Field Intensity, Electric Flux Density, Gauss's Law, Divergence, Electric field and potential due to point, line, plane and spherical charge distributions, Effect of dielectric medium, Capacitance of simple configurations, Biot-Savart's law, Ampere's law, Curl, Faraday's law, Lorentz force, Inductance, Magnetomotive force, Reluctance, Magnetic circuits, Self and Mutual inductance of simple configurations.
- **Signals and Systems:** Representation of continuous and discrete time signals, shifting and scaling properties, linear time invariant and causal systems, Fourier series representation of continuous and discrete time periodic signals, sampling theorem, Applications of Fourier Transform for continuous and discrete time signals, Laplace Transform and Z transform. R.M.S. value, average value calculation for any general periodic waveform
- **Electrical Machines:** Single phase transformer, equivalent circuit, phasor diagram, open circuit and short circuit tests, regulation and efficiency; Three-phase transformers: connections, vector groups, parallel operation; Auto-transformer, Electromechanical energy conversion principles; DC machines: separately excited, series and shunt, motoring and generating mode of

operation and their characteristics, speed control of dc motors; Three-phase induction machines: principle of operation, types, performance, torque- speed characteristics, no-load and blocked-rotor tests, equivalent circuit, starting and speed control; Operating principle of single-phase induction motors; Synchronous machines: cylindrical and salient pole machines, performance and characteristics, regulation and parallel operation of generators, starting of synchronous motors; Types of losses and efficiency calculations of electric machines

- **Power Systems:** Basic concepts of electrical power generation, ac and dc transmission concepts, Models and performance of transmission lines and cables, Economic Load Dispatch (with and without considering transmission losses), Series and shunt compensation, Electric field distribution and insulators, Distribution systems, Per-unit quantities, Bus admittance matrix, Gauss- Seidel and Newton-Raphson load flow methods, Voltage and Frequency control, Power factor correction, Symmetrical components, Symmetrical and unsymmetrical fault analysis, Principles of over-current, differential, directional and distance protection; Circuit breakers, System stability concepts, Equal area criterion.
- **Control Systems:** Mathematical modeling and representation of systems, Feedback principle, transfer function, Block diagrams and Signal flow graphs, Transient and Steady-state analysis of linear time invariant systems, Stability analysis using Routh-Hurwitz and Nyquist criteria, Bode plots, Root loci, Lag, Lead and Lead Lag compensators; P, PI and PID controllers; State space model, Solution of state equations of LTI systems
- **Electrical and Electronic Measurements:** Bridges and Potentiometers, Measurement of voltage, current, power, energy and power factor; Instrument transformers, Digital voltmeters and multimeters, Phase, Time and Frequency measurement; Oscilloscopes, Error analysis.
- **Analog and Digital Electronics:** Simple diode circuits: clipping, clamping, rectifiers; Amplifiers: biasing, equivalent circuit and frequency response; oscillators and feedback amplifiers; operational amplifiers: characteristics and applications; single stage active filters, Sallen Key, Butterworth, VCOs and timers, combinatorial and sequential logic circuits, multiplexers, demultiplexers, Schmitt triggers, sample and hold circuits, A/D and D/A converters.
- **Power Electronics:** Static V-I characteristics and firing/gating circuits for Thyristor, MOSFET, IGBT; DC to DC conversion: Buck, Boost and Buck-Boost Converters; Single and three-phase configuration of uncontrolled rectifiers; Voltage and Current commutated Thyristor based converters; Bidirectional ac to dc voltage source converters; Magnitude and Phase of line current harmonics for uncontrolled and thyristor based converters; Power factor and Distortion Factor of ac to dc converters; Single-phase and three phase voltage and current source inverters, sinusoidal pulse width modulation.

Electronics Engineering (B):

- **Engineering Mathematics: Linear Algebra**: Vector space, basis, linear dependence and independence, matrix algebra, eigenvalues and eigenvectors, rank, solution of linear equations- existence and uniqueness.
- **Calculus:** Mean value theorems, theorems of integral calculus, evaluation of definite and improper integrals, partial derivatives, maxima and minima, multiple integrals, line, surface and volume integrals, Taylor series.
- **Differential Equations**: First order equations (linear and nonlinear), higher order linear differential equations, Cauchy's and Euler's equations, methods of solution using variation of parameters, complementary function and particular integral, partial differential equations, variable separable method, initial and boundary value problems.
- **Vector Analysis**: Vectors in plane and space, vector operations, gradient, divergence and curl, Gauss's, Green's and Stokes' theorems.
- **Complex Analysis**: Analytic functions, Cauchy's integral theorem, Cauchy's integral formula, sequences, series, convergence tests, Taylor and Laurent series, residue theorem.
- **Probability and Statistics**: Mean, median, mode, standard deviation, combinatorial probability, probability distributions, binomial distribution, Poisson distribution, exponential distribution, normal distribution, joint and conditional probability
- **Networks, Signals and Systems: Circuit analysis**: Node and mesh analysis, superposition, Thevenin's theorem, Norton's theorem, reciprocity. Sinusoidal steady state analysis: phasors, complex power, maximum power transfer. Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform, Linear 2-port network parameters, wye-delta transformation. **Continuous-time signals**: Fourier series and Fourier transform, sampling theorem and applications, **Discrete-time signals**: DTFT, DFT, z-transform, discrete-time processing of continuous-time signals. LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay
- **Electronic Devices:** Energy bands in intrinsic and extrinsic semiconductors, equilibrium carrier concentration, direct and indirect band-gap semiconductors, **Carrier transport**: diffusion current, drift current, mobility and resistivity, generation and recombination of carriers, Poisson and continuity equations, P-N junction, Zener diode, BJT, MOS capacitor, MOSFET, LED, photo diode and solar cell
- **Analog Circuits: Diode circuits**: clipping, clamping and rectifiers, **BJT and MOSFET amplifiers**: biasing, ac coupling, small signal analysis, frequency response. Current mirrors and differential amplifiers,
- **Op-amp circuits**: Amplifiers, summers, differentiators, integrators, active filters, Schmitt triggers and oscillators
- **Digital Circuits:Number representations**: binary, integer and floating-point- numbers. Combinatorial circuits: Boolean algebra, minimization of functions using Boolean identities and Karnaugh map, logic gates and their static CMOS implementations, arithmetic circuits, code converters, multiplexers, decoders.

- **Sequential circuits**: latches and flip-flops, counters, shift-registers, finite state machines, propagation delay, setup and hold time, critical path delay, **Data converters**: sample and hold circuits, ADCs and DACs.
- **Semiconductor memories**: ROM, SRAM, DRAM, **Computer organization**: Machine instructions and addressing modes, ALU, data-path and control unit, instruction pipelining
- **Control Systems:** Basic control system components; Feedback principle; Transfer function; Block diagram representation; Signal flow graph; Transient and steady-state analysis of LTI systems; Frequency response; Routh-Hurwitz and Nyquist stability criteria; Bode and root-locus plots; Lag, lead and lag lead compensation; State variable model and solution of state equation of LTI systems.
- **Communications: Random processes**: autocorrelation and power spectral density, properties of white noise, filtering of random signals through LTI systems, **Analog communications**: amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, super heterodyne receivers, **Information theory**: entropy, mutual information and channel capacity theorem, **Digital communications**: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK, QAM), bandwidth, inter-symbol interference, MAP, ML detection, matched filter receiver, SNR and BER. Fundamentals of error correction, Hamming codes, CRC.
- **Electromagnetics: Maxwell's equations**: differential and integral forms and their interpretation, boundary conditions, wave equation, Poynting vector, **Plane waves and properties**: reflection and refraction, polarization, phase and group velocity, propagation through various media, skin depth, **Transmission lines**: equations, characteristic impedance, impedance matching, impedance transformation, S-parameters, Smith chart, Rectangular and circular waveguides, light propagation in optical fibers, dipole and monopole antennas, linear antenna arrays.

Computer Science:

- **Basic Mathematics**: linear algebra: vector and matrix properties and operations, solving systems of linear equations; probability and statistics, random variables, random processes
- **Basic Programming Concepts**: Iterative programming (for and while loop constructs), conditional executions, functions, pointers, recursions, fIle handling, procedural and object oriented programming concepts
- **Data Structures**: Linear data structures: arrays, stack, queue, linked lists; non-linear data structures: binary search tree, balanced binary search tree, heap tree, graphs; representation of data structures in computer memory; applications and complexity of operations on / using data structures
- **Design and Analysis of Algorithms:** Asymptotic notations, sorting and search- insertion sort, selection sort, merge sort, quicksort, binary search, design techniques: divide and conquer, greedy, dynamic programming, data structures: heaps, union of disjoint sets, search trees, algorithms on graphs: exploration, connectivity, shortest paths, directed acyclic graphs, spanning trees, Intractability: NP completeness, reductions

- **Computer networks:** TCP/IP protocol stack and design of Internet, application layer: HTTP, FTP, DNS, P2P file sharing, transport layer: Issues related to process-to process communication and reliable data transfer, TCP and UDP operations; network layer: routing, addressing, QoS issues, IPv4 and IPv6 protocols; data link layer: wired and wireless local area networks and protocols
- **Digital Logic Design:** Boolean algebra, logic gates, design of combinational logic circuits - adder, subtractor, multiplier, comparator; sequential logic circuits - flip-flops, registers, counters
- **Computer Organization:** Machine instructions and addressing modes. ALU, data-path and control unit. Instruction pipelining, pipeline hazards. Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode)
- **Theory of Computation:** Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and contex-free languages, pumping lemma. Turing machines and undecidability
- **Compiler Design:** Lexical analysis, parsing, syntax-directed translation. Runtime environments. Intermediate code generation. Local optimisation, Data flow analyses: constant propagation, liveness analysis, common subexpression elimination
- **Databases:** ER-model. Relational model: relational algebra, tuple calculus, SQL. Integrity constraints, normal forms. File organization, indexing (e.g., B and B+ trees). Transactions and concurrency control
- **Operating Systems:** Interprocess communication, deadlock, memory management, file system design, device/IO management

Part-II

DEPARTMENT OF MECHANICAL AND AERO-SPACE ENGINEERING

Aero-Space Engineering:

- **Engineering Mathematics:** Linear Algebra, Calculus, Differential Equations, Fourier Series, Laplace Transform, Numerical methods for linear and nonlinear algebraic equations, Numerical integration and differentiation, Complex analysis, Probability and statistics.
- **Aerodynamics:** Governing equations of fluid dynamics, Boundary layer separation, Internal and external flows, Drag and Lift, non-dimensional parameters, airfoils, angle of attack, potential flow theory, Zhukovsky transformation, fundamentals of CFD, N-S and Euler Equations, mesh generation, stability, convergence, numerical schemes for elliptic, parabolic and hyperbolic equations, Basic understanding of Finite Volume Method.
- **Aerospace structures:** Analysis of axial members, transverse members, and torsional members, Statically indeterminate members, stresses in combined loading, Buckling of columns; Stress and displacement formulations, Airy's stress function, Prandtl stress function, st. Venant warping functions, membrane analogy, torsion in narrow rectangular section; Torsional shear flows in thin-walled open and closed sections, Flexural shear flows in thin-walled open and closed sections; SDOF systems, 2/MDOF systems, vibration of continuous system/ (Theory of Elasticity); fundamentals of composite materials, material engineering, design & manufacturing.
- **Flight Mechanics and Control:** Basics, Airplane performance, Static stability, Dynamic stability, Euler angles, Equations of motion; aerodynamic forces and moments, stability & control derivatives; decoupling of longitudinal and lateral-directional dynamics; longitudinal modes; lateral-directional modes, UAV design, development and deployment, Guidance, navigation and control, Path planning, Aircraft System Identification.
- **Propulsion:** Basics, Aerothermodynamics of aircraft engines, Engine performance, Turbomachinery, Centrifugal compressor, Rocket propulsion, Axial and Radial flow turbines, Aerothermodynamics of non-rotating propulsion components such as intakes, combustor and nozzle, Turbine blade cooling, Compressor-turbine matching, Surge and stall, Turbojet & Turboprop, Turbo-shaft Engines; The Engine Operating Lines; Operational details of multiple shaft engines, Ramjets, Pulsejets and Scramjets, Augmentation of thrust.

Mechanical Engineering:

- **Engineering Mechanics:** Free body diagrams and equilibrium, Trusses and frames, Kinematics and dynamics of particles and of rigid bodies in plane motion, Impulse and momentum, Center of gravity, Moment of inertia, Friction, Energy formulations, Virtual work,
- **Mechanics of Materials:** Stress and strain, Analysis of stress and strain, Elastic constants, Poisson's ratio, Mohr's circle for plane stress and plane

strain, Shear force and bending moment diagrams, Deflection of beams. Torsion of circular shafts, Euler's theory of columns, energy methods, Theories of failure, Stresses in hollow and solid discs, Stresses in rotating disc of constant thickness.

- **Theory of Machines:** Kinematics & kinetics of mechanisms, lower pairs & higher pairs, mechanisms and DOF, inversions, velocity and acceleration analysis, instantaneous centre, Balancing of reciprocating and rotating masses, Analysis of governors, flywheels, gears and cams, linear mechanical vibrations, free and forced vibrations, vibrations of single and multiple degree of freedom systems, Effect of damping, Vibration isolation, Resonance, Critical speeds of shafts.
- **Machine Design:** Design for static and dynamic loading, SN curves and fatigue, concept of factor of safety in design, Design of machine elements for bolted, riveted and welded joints, Design of shafts, gears, brakes and springs.
- **Thermodynamics:** Zeroth law of thermodynamics, temperature scales, first and second law of thermodynamics, heat engines, Application of steady state flow process, Carnot cycle, Otto cycle, Diesel cycle, Rankine cycle, Brayton cycle, Vapour compression refrigeration cycle, Heat pumps, Gas refrigeration, Reverse Brayton cycle.
- **Heat transfer:** Basic modes of heat transfer, General heat conduction equation, Steady and unsteady heat conduction, Natural and forced convection, Laws of radiation. Heat exchanger performance, LMTD and NTU methods.
- **Fluid Mechanics and Hydraulic Machinery:** Fluid properties- Viscosity, Hydrostatics- Buoyancy, Bernoulli's equation, Differential equation of continuity and momentum, boundary layer, Flow measurement– Pipes and pipe fittings, Pumps, Compressors and Turbines. Work output and efficiency of hydraulic machinery, water turbines, pumps, dimensional analysis and similitude.
- **Materials Science:** Structure and properties of engineering materials, heat treatment, stress-strain diagrams for engineering materials, Atomic packing factor, Volume, planar and linear atomic density, Crystallographic planes and directions, Gibbs phase rule, Cooling curves, Phase diagrams.
- **Measurements and Instrumentation:** Generalized measurement system, Standards, Calibration, Uncertainty, Errors, Hydraulic and pneumatic load cells, Instruments for high, mid and low pressure measurement, Flow measuring devices, Temperature measurement and sensing techniques, Limits, fits and tolerances, Linear and angular measurements, comparators, Gauge design, Interferometry, Form and finish measurement, tolerance analysis in manufacturing and assembly.
- **Manufacturing:** ***Theory of metal cutting:*** Orthogonal and oblique machining, Single point cutting tool and tool signature, Chip formation, cutting forces, Merchant's analysis, Specific cutting energy and power, Machining parameters and material removal rate, tool materials, Tool wear and tool life, Thermal aspects of machining, cutting fluids, machinability, Machining time calculation. Lathe, Drilling and Milling operations. Metal forming and casting, sheet (shearing, deep drawing, bending) metal forming processes, Principles of powder metallurgy, Unconventional Machining Processes (EDM, WEDM, LBM, ECM, etc.), Cryogenic machining, Computer controlled machines, CAD/CAM, Principles of welding, brazing, soldering and adhesive bonding.

- ***Automation in manufacturing***: Industrial robots – configurations, drives and controls, Cellular manufacturing and FMS - Group Technology, CAPP.
- ***Industrial Engineering:*** Constraint and unconstraint optimization techniques, Practical aspects of optimization, Forecasting, Aggregate production planning and scheduling, Inventory analysis and control, Project planning, Linear programming, Transportation-Assignment models, Sequencing, Simple queuing, Capacity planning, Plant and facility layout, Plant location, Production and assembly line balancing, Time and motion study, Work sampling, Predetermined time systems, Principles of motion economy, Industrial safety, Cost concepts and Break Even analysis.