Written Test Syllabus for M. Tech. (Biomedical Engineering) Admission

Written test will have the following six sections and a candidate has to choose any two (2) of these six (6) sections for writing the exam:

1. Biology
2. Chemistry
3. Physics
4. Mathematics
5. Physiology
6. Engineering (Section A or Section B). Candidates who choose the Engineering section have to **choose either Section A OR Section B**.

Only the two sections chosen by the candidate should be attempted and evaluated (e.g.: Biology and Engineering-Section A, Chemistry and Physics, Physiology and Engineering-Section B, etc.).

The question paper for each section will comprise of 10 questions, 1 mark each. There will be no negative marking.

Use of a scientific calculator during the written test will be permitted, candidates should bring their own scientific calculator (mobiles, etc. will not be allowed).

Syllabus for each section will be at a level comparable to that for latest GATE examination or equivalent test/exam. **The syllabus for each section is given below:**

1. Biology

Biochemistry: Organization of life; Importance of water; Structure and function of biomolecules: Amino acids, Carbohydrates, Lipids, Proteins and Nucleic acids; Protein structure, folding / misfolding and function; Myoglobin, Hemoglobin, Lysozyme, Ribonuclease A, Carboxypeptidase and Chymotrypsin.

Enzyme kinetics, regulation and inhibition; Vitamins and Coenzymes; Bioenergetics and metabolism; Generation and utilization of ATP; Metabolic pathways and their regulation: glycolysis, TCA cycle, pentose phosphate pathway, oxidative phosphorylation, gluconeogenesis, glycogen and fatty acid metabolism; Metabolism of Nitrogen containing compounds: nitrogen fixation, amino acids and nucleotides. Photosynthesis, Calvin cycle.

Biochemical separation techniques: ion exchange, size exclusion and affinity chromatography, centrifugation; Characterization of biomolecules by electrophoresis; DNA- protein and protein – protein interactions; UV-visible and fluorescence spectroscopy; Mass spectrometry.

Cell structure and organelles; Biological membranes; Action potential; Transport across membranes; Membrane assembly and Protein targeting; Signal transduction; Receptor-ligand interaction; Hormones and neurotransmitters.

DNA replication, transcription and translation; DNA damage and repair; Biochemical regulation of gene expression; Recombinant DNA technology and applications: PCR, site directed mutagenesis, DNA-microarray; Next generation sequencing; Gene silencing and editing.

Immune system: Innate and adaptive; Cell of the immune system; Active and passive immunity; Complement system; Antibody structure, function and diversity; B cell and T Cell receptors; B cell and T cell activation; Major histocompatibilty complex; Immunological techniques: Immuno diffusion, immune-electrophoresis, RIA and ELISA, flow cytometry; monoclonal antibodies and their applications.

Botany:

Plant Systematics

Botanical nomenclature, history of plant taxonomy, diversity and classification of plants, APG system of plant classification; phylogenetics and cladistics, molecular taxonomy and DNA barcoding; Centers for plant taxonomy and herbaria in India.

Plant Anatomy

Anatomy of root, stem and leaves, floral organs, embryo and young seedlings, Primary and secondary meristems, stellar organization, vascular system and their ontogeny, xylem and phloem structure, secondary growth in plants and wood anatomy, plant cell structure and differences from animal cells.

Plant development; cell and tissue morphogenesis

Life cycle of an angiosperm, development of male and female gametophyte; cell fate determination and tissue patterning; spacing mechanisms in trichomes and stomata. Embryogenesis, organization and function of shoot and root apical meristems. Transition to flowering: photoperiodism and vernalization, ABC model of floral organ patterning, pollen germination, double fertilization, seed development; Xylem and phloem cell differentiation, photomorphogenesis; phytochrome, cryptochrome, phototropin. Role of auxin, cytokinin, gibberellins, and brassinosteroids on plant development.

Plant physiology and biochemistry

Plant water relations, mechanisms of uptake and transport of water, ions, solutes from soil to plants, apoplastic and symplastic transport mechanisms. Mechanism of stomatal movements, nitrogen metabolism, photosynthesis; C3, C4 and CAM cycles, photorespiration, respiration: glycolysis, TCA cycle and electron transport chain. Plant responses and mechanisms of abiotic stresses including drought, salinity, freezing and heat stress, metal toxicity; role of abscisic acid in abiotic stresses. Structure and function of biomolecules (proteins, carbohydrates, lipids, nucleic acid), enzyme kinetics. Structure and biosynthesis of major plant secondary metabolites (alkaloids, terpenes, phenylpropanoids, flavonoids). Biosynthesis, mechanism of action and physiological effects of auxin, cytokinin, gibberellic acids, brassinosteroid, ethylene, strigolactone, abscisic acid, salicylic and jasmonic acid. Senescence and programmed cell death.

Genetics and genomics

Cell cycle and cell division. Principles of Mendelian inheritance, linkage, recombination, genetic mapping; extra chromosomal inheritance; Introduction to epigenetics; gene silencing- transgene silencing, post transcriptional gene silencing, miRNA and siRNA; evolution and organization of eukaryotic genome structure, gene expression, gene mutation and repair, chromosomal aberrations (numerical: euploidy and aneuploidy and structural: deletion, duplication, inversion, translocation), transposons. Model organisms for functional genetics and genomics; Introduction to transcriptomics, proteomics and metabolomics.

Plant Breeding, Genetic Modification, Genome Editing

Principles, methods – selection, hybridization, heterosis; male sterility, genetic maps and molecular markers, embryo rescue, haploid and doubled haploids, plant tissue culture: micropropagation, embryo culture and in vitro regeneration, somatic embryogenesis, artificial seed, cryopreservation, somaclonal variation, somatic cell hybridization, marker-assisted selection, gene transfer methods viz. direct and vector-mediated, generation of transgenic plants; Introduction to genome editing: CRISPR/Cas9, Cre-Lox system to generate chimeras; plastid transformation; chemical mutagenesis.

Economic and applied Botany

A general account of economically and medicinally important plants- cereals, pulses, plants yielding fibers, timber, sugar, beverages, oils, rubber, pigments, dyes, gums, drugs and narcotics. Economic importance of algae, fungi, lichen and bacteria. Major Indian cash crops. Effect of industrialization on agricultural botany such as plastic on fiber economy. Genetically modified crops and its regulation eg. Bt cotton, Btbrinjal golden rice etc.

Plant Pathology

Nature and classification of plant diseases, diseases of important crops caused by fungi, bacteria, nematodes and viruses, and their control measures (chemical and biological) mechanism(s) of pathogenesis, resistance: basal, systemic, induced systemic resistance, gene for gene concept. Molecular detection of pathogens; plant-microbe interactions: symbionts and mycorrhiza, pathogens and pests. Signaling pathways in plant defence response; salicylic acid (SA) and jasmonic acid (JA) in plant-pathogen and plant-herbivore interaction, necrosis; host-parasitic plant interaction (such as Cuscuta).

Ecology and Environment

Ecosystems – types, dynamics, degradation, biogeochemical cycles, ecological succession; food webs and energy flow through ecosystem; vegetation types of the world, Indian vegetation types and biogeographical zones, climate and flora endemism; pollution and global climate change, speciation and extinction, biodiversity and conservation strategies, ecological hotspots, afforestation, habitat restoration; plant interactions with other organisms; epiphytes, parasites and endophytes.

Microbiology:
Historical Perspective

Discovery of microbial world; Landmark discoveries relevant to the field of microbiology; Controversy over spontaneous generation; Role of microorganisms in transformation of organic matter and in the causation of diseases.

Methods in Microbiology

Pure culture techniques; Principles of microbial nutrition; Enrichment culture techniques for isolation of microorganisms; antigen and antibody detection methods for microbial diagnosis; Light-, phase contrast-, fluorescence- and electron-microscopy; PCR, real-time PCR for quantitation of microbes; Next generation sequencing technologies in microbiology.

Microbial Taxonomy and Diversity

Bacteria, Archea and their broad classification; Eukaryotic microbes: Yeasts, molds and protozoa; Viruses and their classification; Molecular approaches to microbial taxonomy and phylogeny.

Prokaryotic Cells: Structure and Function

Prokaryotic Cells: cell walls, cell membranes and their biosynthesis, mechanisms of solute transport across membranes, Flagella and Pili, Capsules, Cell inclusions like endospores and gas vesicles; Bacterial locomotion, including positive and negative chemotaxis.

Microbial Growth

Definition of growth; Growth curve; Mathematical expression of exponential growth phase; Measurement of growth and growth yields; Synchronous growth; Continuous culture; Effect of environmental factors on growth; Bacterial biofilm and biofouling.

Control of Micro-organisms

Disinfection and sterilization: principles, methods and assessment of efficacy.

Microbial Metabolism

Energetics: redox reactions and electron carriers; Electron transport and oxidative phosphorylation; An overview of metabolism; Glycolysis; Pentose-phosphate pathway; Entner-Doudoroff pathway; Glyoxalate pathway; The citric acid cycle; Fermentation; Aerobic and anaerobic respiration; Chemolithotrophy; Photosynthesis; Calvin cycle; Biosynthetic pathway for

fatty acids synthesis; Common regulatory mechanisms in synthesis of amino acids; Regulation of major metabolic pathways.

Microbial Diseases and Host Pathogen Interaction

Normal microbiota; Classification of infectious diseases; Reservoirs of infection; Nosocomial infection; Opportunistic infections; Emerging infectious diseases; Mechanism of microbial pathogenicity; Nonspecific defense of host; Antigens and antibodies; Humoral and cell mediated immunity; Vaccines; passive immunization; Immune deficiency; Human diseases caused by viruses, bacteria, and pathogenic fungi.

Chemotherapy/Antibiotics

General characteristics of antimicrobial drugs; Antibiotics: Classification molecular mechanism of mode of action and resistance; Antifungal and antiviral drugs.

Microbial Genetics

Types of mutation; UV and chemical mutagens; Selection of mutants; Ames test for mutagenesis; Bacterial genetic system: transformation, conjugation, transduction, recombination, plasmids, transposons; DNA repair; Regulation of gene expression: repression and induction; Operon model; Bacterial genome with special reference to *E.coli*; Phage λ and its life cycle; RNA ; mutation in virus genomes, virus recombination and reassortment; Basic concept of microbial genomics.

Microbial Ecology

Microbial interactions; Carbon, sulphur and nitrogen cycles; Soil microorganisms associated with vascular plants; Bioremediation; Uncultivable microorganisms; basic concept of metagenomics and metatranscriptomics.

Zoology:
Animal Diversity

Distribution, systematics and classification of animals, phylogenetic relationships (based on classical and molecular phylogenetic tools).

Evolution

Origin and history of life on earth, theories of evolution, natural selection, adaptation, speciation.

Genetics

Basic Principles of inheritance, molecular basis of heredity, sex determination and sex-linked characteristics, cytoplasmic inheritance, linkage, recombination and mapping of genes in eukaryotes, population genetics, genetic disorders, roles of model organisms in understanding genetic principles.

Biochemistry and Molecular Biology

Nucleic acids, proteins, lipids and carbohydrates; replication, transcription and translation, Krebs cycle, glycolysis, enzyme catalysis, hormones and their actions, roles of vitamins and minerals.

Cell Biology

Basic principles of cellular microscopy, structure of cell, cytoskeletal organization, cellular organelles and their structure and function, cell cycle, cell division, chromosomes and chromatin structure.

Gene expression in Eukaryotes

Eukaryotic genome organization and regulation of gene expression, transposable elements.

Animal Anatomy and Physiology

Comparative physiology, the respiratory system, Muscular system, circulatory system, digestive system, the nervous system, the excretory system, the endocrine system, the reproductive system, the skeletal system.

Parasitology and Immunology

Nature of parasite, host-parasite relation, protozoan and helminthic parasites, the immune response, cellular and humoral immune response.

Development Biology

Gametogenesis, Embryonic development, cellular differentiation, organogenesis, metamorphosis, Model organisms used in developmental biology, genetic and molecular basis of development, stem cells.

Ecology

The ecosystem, Animal distribution, ecological niche and its contribution to ecological diversity, the food chain, population dynamics, species diversity, zoogeography, biogeochemical cycles, conservation biology, ecotoxicology.

Animal Behaviour

Type of behaviours, courtship, mating and territoriality, instinct, learning and memory, social behaviour across the animal taxa, communication, pheromones, evolution of behavior in animals.

Genetics and Evolutionary Biology: Mendelian inheritance; Gene interaction; Complementation; Linkage, recombination and chromosome mapping; Extra chromosomal inheritance; Microbial genetics - transformation, transduction and conjugation; Horizontal gene transfer and transposable elements; Chromosomal variation; Genetic disorders; Population genetics; Epigenetics; Selection and inheritance; Adaptive and neutral evolution; Genetic drift; Species and speciation.

Cell Biology: Prokaryotic and eukaryotic cell structure; Cell cycle and cell growth control; Cell- cell communication; Cell signalling and signal transduction; Post-translational modifications; Protein trafficking; Cell death and autophagy; Extra-cellular matrix.

Molecular Biology: Molecular structure of genes and chromosomes; Mutations and mutagenesis; Regulation of gene expression; Nucleic acid - replication, transcription, splicing, translation and their regulatory mechanisms; Non-coding and micro RNA; RNA interference; DNA damage and repair.

Bioreaction engineering: Rate law, zero and first order kinetics; Ideal reactors - batch, mixed flow and plug flow; Enzyme immobilization, diffusion effects - Thiele modulus, effectiveness factor, Damkoehler number; Kinetics of cell growth, substrate utilization and product formation; Structured and unstructured models; Batch, fed-batch and continuous processes; Microbial and enzyme reactors; Optimization and scale up.

Upstream and Downstream Processing: Media formulation and optimization; Sterilization of air and media; Filtration - membrane filtration, ultra filtration; Centrifugation - high speed and ultra; Cell disruption; Principles of chromatography - ion exchange, gel filtration, hydrophobic interaction, affinity, GC, HPLC and FPLC; Extraction, adsorption and drying.

Instrumentation and Process Control: Pressure, temperature and flow measurement devices; Valves; First order and second order systems; Feedback and feed forward control; Types of controllers – proportional, derivative and integral control, tuning of controllers.

Recombinant DNA technology: Restriction and modification enzymes; Vectors - plasmids, bacteriophage and other viral vectors, cosmids, Ti plasmid, bacterial and yeast artificial chromosomes; Expression vectors; cDNA and genomic DNA library; Gene isolation and cloning, strategies for production of recombinant proteins; Transposons and gene targeting;

Molecular tools: Polymerase chain reaction; DNA/RNA labelling and sequencing; Southern and northern blotting; In-situ hybridization; DNA fingerprinting, RAPD, RFLP; Site-directed mutagenesis; Gene transfer technologies; CRISPR-Cas; Biosensing and biosensors.

Analytical tools: Principles of microscopy - light, electron, fluorescent and confocal; Principles of spectroscopy - UV, visible, CD, IR, fluorescence, FT-IR, MS, NMR; Electrophoresis; Micro- arrays; Enzymatic assays; Immunoassays - ELISA, RIA, immunohistochemistry; immunoblotting; Flow cytometry; Whole genome and ChIP sequencing.

Computational tools: Bioinformatics resources and search tools; Sequence and structure databases; Sequence analysis - sequence file formats, scoring matrices, alignment, phylogeny; Genomics, proteomics, metabolomics; Gene prediction; Functional annotation; Secondary structure and 3D structure prediction; Knowledge discovery in biochemical databases; Metagenomics; Metabolic engineering and systems biology.

2. Chemistry

Atomic Structure and Periodicity

Planck's quantum theory, wave particle duality, uncertainty principle, comparison between Bohr's model and quantum mechanical model of hydrogen atom, electronic configuration of atoms and ions. Hund's rule and Pauli's exclusion principle.
Periodic table and periodic properties: ionization energy, electron affinity, electronegativity and atomic size.

Structure and Bonding

Ionic and covalent bonding, MO and VB approaches for diatomic molecules, VSEPR theory and shape of molecules, hybridization, resonance, dipole moment, structure parameters such as

bond length, bond angle and bond energy, hydrogen bonding and van der Waals interactions. Ionic solids, ionic radii and lattice energy (Born-Haber cycle). HSAB principle.

s, p and d Block Elements

Oxides, halides and hydrides of alkali, alkaline earth metals, B, Al, Si, N, P, and S. General characteristics of 3d elements. Coordination complexes: valence bond and crystal field theory, color, geometry, magnetic properties and isomerism.

Chemical Equilibria

Osmotic pressure, elevation of boiling point and depression of freezing point, ionic equilibria in solution, solubility product, common ion effect, hydrolysis of salts, pH, buffer and their applications. Equilibrium constants (Kc, Kp and Kx) for homogeneous reactions.

Electrochemistry

Conductance, Kohlrausch law, cell potentials, EMF, Nernst equation, thermodynamic aspects and their applications.

Reaction Kinetics

Rate constant, order of reaction, molecularity, activation energy, zero, first and second order kinetics, catalysis and elementary enzyme reactions. Reversible and irreversible inhibition of enzymes.

Thermodynamics

Qualitative treatment of state and path functions, First law, reversible and irreversible processes, internal energy, enthalpy, Kirchoff equation, heat of reaction, Hess's law, heat of formation. Second law, entropy and free energy. Gibbs-Helmholtz equation, free energy change and spontaneity, Free energy changes from equilibrium constant.

Structure-Reactivity Correlations and Organic Reaction Mechanisms

Acids and bases, electronic and steric effects, Stereochemistry, optical and geometrical isomerism, tautomerism, conformers and concept of aromaticity. Elementary treatment of SN1, SN2, E1, E2 and radical reactions, Hoffmann/Saytzeff rules, addition reactions, Markownikoff rule and Kharasch effect. Elementary hydroboration reactions. Grignard's reagents and their uses. Aromatic electrophilic substitutions, orientation effect as exemplified by various functional groups. Identification of common functional groups by chemical tests.

Chemistry of Biomolecules

Amino acids, proteins, nucleic acids and nucleotides. Peptide sequencing by chemical and enzymatic proteolytic methods. DNA sequencing by chemical and enzymatic methods. Carbohydrates (upto hexoses only). Lipids (triglycerides only). Principles of biomolecule purification-Ion exchange and gel filtration chromatography. Identification of these biomolecules and Beer-Lambert's law.

3. Physics

Dimensional analysis, vector algebra
Classical mechanics: motion in one dimension, Newton's laws
Electricity: Coulomb's law, electric field and potential, Ohm's law, current and resistance
Optics: lenses, mirrors and focal length, interference and diffraction, Young's double slit experiment
Heat and thermodynamics: laws of thermodynamics, concepts of temperature, energy and entropy

4. Mathematics

Linear Algebra: Matrix algebra, systems of linear equations, Eigenvalues and Eigenvectors.

Calculus: Mean value theorems, theorems of integral calculus, partial derivatives, maxima and minima, multiple integrals, Fourier series, vector identities, line, surface and volume integrals, Stokes, Gauss and Green's theorems.

Differential equations: First order linear and nonlinear differential equations, higher order linear differential equations with constant coefficients, method of separation of variables, Cauchy's and Euler's equations, initial and boundary value problems, and solution of partial differential equations.

Analysis of complex variables: Analytic functions, Cauchy's integral theorem and integral formula, Taylor's and Laurent's series, residue theorem.

Probability and Statistics: Sampling theorems, conditional probability, mean, median, mode and standard deviation, random variables, discrete and continuous distributions: normal, Poisson and

binomial distributions. Tests of Significance, statistical power analysis, and sample size estimation. Linear Regression and correlation analysis;

Numerical Methods: Matrix inversion, numerical solutions of nonlinear algebraic equations, iterative methods for solving differential equations, numerical integration.

5. Physiology

Human physiology, focusing on the following systems: Nervous, Musculoskeletal, Cardiovascular, Respiratory, and Renal.

6. Engineering

[Candidates who choose the Engineering section have to choose either Section A OR Section B]

Section A:

Electrical Circuits:

Voltage and current sources - independent, dependent, ideal and practical; v-i relationships of resistor, inductor and capacitor; transient analysis of RLC circuits with dc excitation; Kirchoff's laws, superposition, Thevenin, Norton, maximum power transfer and reciprocity theorems; Peak, average and rms values of ac quantities; apparent, active and reactive powers; phasor analysis, impedance and admittance; series and parallel resonance, realization of basic filters with R, L and C elements, Bode plot.

Signals and Systems:

Continuous and Discrete Signal and Systems - Periodic, a periodic and impulse signals; Sampling theorem; Laplace and Fourier transforms; impulse response of systems; transfer function, frequency response of first and second order linear time invariant systems, convolution, correlation. Discrete time systems - impulse response, frequency response, DFT, Z - transform; basics of IIR and FIR filter.

Sensors and Bioinstrumentation:

Sensors - resistive, capacitive, inductive, piezoelectric, Hall effect, electro chemical, optical; Sensor signal conditioning circuits; application of LASER in sensing and therapy. Origin of bio potentials and their measurement techniques - ECG, EEG, EMG, ERG, EOG, GSR, PCG, Principles of measuring blood pressure, body temperature, volume and flow in arteries, veins and tissues, respiratory measurements and cardiac output measurement. Operating principle of medical equipment-sphygmomanometer, ventilator, cardiac pacemaker, defibrillator, pulse oximeter, hemodialyzer Electrical Isolation (optical and electrical) and Safety of Biomedical Instruments.

Section B:

Biomechanics:

Kinematics of muscles and joints - free-body diagrams and equilibrium, forces and stresses in joints, biomechanical analysis of joints, Gait analysis; Hard Tissues - Definition of Stress and Strain, Deformation Mechanics, structure and mechanical properties of bone - cortical and cancellous bones; Soft Tissues - Structure, functions, material properties, visco elastic properties, Maxwell & Voight models; Biofluid mechanics - Flow properties of blood in the intact human cardiovascular system.

Biomaterials:

Basic properties of biomaterials - Metallic, Ceramic, Polymeric and Composite; Fundamental characteristics of implants - biocompatibility, bioactivity, biodegradability; Basics of drug delivery; Basics of tissue engineering. Biomaterial characterization techniques - Rheology, Atomic Force Microscopy, Electron Microscopy, Transmission Electron Microscopy Fourier Transform Infrared Spectroscopy.

Process Calculations and Thermodynamics

Steady and unsteady state mass and energy balances including multiphase, multi-component, reacting and non-reacting systems. Use of tie components; recycle, bypass and purge calculations; Gibb's phase rule and degree of freedom analysis.

First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties

and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.

Fluid Mechanics and Mechanical Operations

Fluid statics, surface tension, Newtonian and non-Newtonian fluids, transport properties, shell-balances including differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis and similitude, flow through pipeline systems, velocity profiles, flow meters, pumps and compressors, elementary boundary layer theory, flow past immersed bodies including packed and fluidized beds, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop.Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids.

Heat Transfer

Equation of energy, steady and unsteady heat conduction, convection and radiation, thermal boundary layer and heat transfer coefficients, boiling, condensation and evaporation; types of heat exchangers and evaporators and their process calculations; design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.

Mass Transfer

Fick's laws, molecular diffusion in fluids, mass transfer coefficients, film, penetration and surface renewal theories; momentum, heat and mass transfer analogies; stage-wise and continuous contacting and stage efficiencies; HTU & NTU concepts; design and operation of equipment for distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption, membrane separations (micro-filtration, ultra-filtration, nano-filtration and reverse osmosis).