7. SCHOOL OF PHYSICAL SCIENCE

The pattern of JNUEE 2020-21 will be based on Multiple Choice Questions (MCQs) through Computer Based Test (CBT)

Master of Science

Sl. No.	Name of Centre	Sub. Code & Sub. Code Number	Syllabus for Entrance Examination
1	School of Physical Sciences (SPS)	Physics- SPSM (226)	**Mathematical Methods:** Calculus of single and multiple real variables. Fourier and Laplace transforms. Vector Calculus, Divergence theorem, Green's theorem, Stokes' theorem. First order and linear second order differential equations with constant coefficients. Matrices and determinants. Complex numbers. **Mechanics and General Properties of Matter:** Newton's laws of motion and applications. Motion under a central force, and Kepler's laws. Elastic and inelastic collisions. Rigid body motion. Principal moments and axes. Kinematics of fluids. Bernoulli's theorem. **Oscillations, Waves and Optics:** Simple harmonic motion. Damped and forced oscillators. Resonance. Wave equation. Group and phase velocities. Sound waves in media. Doppler Effect. Interference and diffraction. Diffraction gratings. Polarization: linear, circular and elliptic polarization. Double refraction and optical rotation. **Electromagnetism:** Coulomb's law. Gauss's law. Electric field and potential. Solution of Laplace's equation for simple cases. Conductors, capacitors, dielectrics. Electrostatic energy. Biot-Savart law, Ampere's law, Faraday's law of electromagnetic induction. LCR circuits. Maxwell's equations and plane electromagnetic waves, Poynting's theorem. Transmission and reflection coefficients (normal incidence only). Lorentz Force and motion of charged particles in electric and magnetic fields. **Thermal and Statistical Physics:** Maxwell-Boltzmann distribution. Equipartition of energy. Ideal gas law. Specific heat. van-der-Waals gas and equation of state. Laws of thermodynamics. First law and its consequences. Isothermal and adiabatic processes. Second law and entropy. Maxwell's thermodynamic relations. Thermodynamic potentials. Fermi-Dirac and Bose-Einstein distributions. **Modern Physics:** Basics of special relativity. Length contraction. Time dilation. Relativistic velocity addition theorem. Mass-energy equivalence. Blackbody radiation. Photoelectric effect. Compton effect. Bohr's atomic model. Pauli exclusion principle. Wave-particle duality. Uncertainty principle. Superposition principle. Schrödinger equation. Particle in a box problem in one, two and three dimensions. Solution of the Schrödinger equation for one dimensional harmonic oscillator. Structure of atomic nucleus, mass and binding energy. Radioactivity. **Solid State Physics, Devices and Electronics:** Crystal structure, Bravais lattices and basis. Miller indices. X-ray diffraction and Bragg's law. Intrinsic and extrinsic semiconductors, variation of resistivity with temperature. Fermi level. p-n junction diode, I-V characteristics, Zener diode and its applications. Transistor characteristics. R-C coupled amplifiers. Operational Amplifiers: Inverting and non-inverting amplifier. Boolean algebra: Binary number systems; binary addition and subtraction. Conversion from one number system to another. Logic Gates AND, OR, NOT, NAND, NOR, X-OR. Truth tables. Combination of gates.

2		Chemistry – CHEM (227)	**PHYSICAL CHEMISTRY** ***Basic Mathematical Concepts***: Functions; maxima and minima; integrals; ordinary differential equations; vectors and matrices; determinants; elementary statistics and probability theory. ***Atomic and Molecular Structure***: Fundamental particles; Bohr's theory of hydrogen-like atom; wave-particle duality; uncertainty principle; Schrödinger's wave equation; quantum numbers; shapes of orbitals; Hund's rule and Pauli's exclusion principle; electronic configuration of simple homonuclear diatomic molecules. ***Theory of Gases***: Equation of state for ideal and non-ideal (van der Waals) gases; Kinetic theory of gases; Maxwell-Boltzmann distribution law; equipartition of energy. ***Solid state****:* Crystals and crystal systems; X-rays; NaCl and KCl structures; close packing; atomic and ionic radii; radius ratio rules; lattice energy; Born-Haber cycle; isomorphism; heat capacity of solids. ***Chemical Thermodynamics***: Reversible and irreversible processes; first law and its application to ideal and nonideal gases; thermochemistry; second law; entropy and free energy; criteria for spontaneity. ***Chemical and Phase Equilibria***: Law of mass action; Kp, Kc, Kx and Kn; effect of temperature on K; ionic equilibria in solutions; pH and buffer solutions; hydrolysis; solubility product; phase equilibria–phase rule and its application to one-component and two-component systems; colligative properties. ***Electrochemistry***: Conductance and its applications; transport number; galvanic cells; EMF and free energy; concentration cells with and without transport; polarography; concentration cells with and without transport; Debey-Huckel-Onsagar theory of strong electrolytes. ***Chemical Kinetics***: Reactions of various order; Arrhenius equation; collision theory; transition state theory; chain reactions – normal and branched; enzyme kinetics; photochemical processes; catalysis. ***Adsorption***: Gibbs adsorption equation; adsorption isotherm; types of adsorption; surface area of adsorbents; surface films on liquids. ***Spectroscopy:*** Beer-Lambert law; fundamental concepts of rotational, vibrational, electronic and magnetic resonance spectroscopy. **ORGANIC CHEMISTRY** ***Basic Concepts in Organic Chemistry and Stereochemistry***: Electronic effects; resonance, inductive, hyperconjugation, aromaticity, tautomerism; organic acids and bases; optical isomerism in compounds with and without any stereocenters (allenes, biphenyls); conformation of acyclic systems (substituted ethane/*n*-propane/*n*-butane) and cyclic systems (mono- and di-substituted cyclohexanes). ***Organic Reaction Mechanism and Synthetic Applications*:** Chemistry of reactive intermediates (carbocations, carbanions, free radicals, carbenes, nitrenes, benzynes); Hofmann-Curtius-Lossen rearrangement, Wolff rearrangement, Simmons-Smith reaction, Reimer-Tiemann reaction, Michael reaction, Darzens reaction, Wittig reaction and McMurry reaction; Pinacol-pinacolone, Favorskii, benzilic acid rearrangement, dienone-phenol rearrangement, Baeyer-Villeger reaction; oxidation and reduction reactions in organic chemistry; organometallic reagents in organic synthesis (Grignard, organolithium and organocopper); Diels-Alder, electrocyclic and sigmatropic reactions; functional group inter-conversions and structural problems using chemical reactions. ***Spectroscopic Analysis***: Identification of functional groups by UV, IR and 1H NMR spectroscopic techniques as tools for structural elucidation. ***Natural Products Chemistry***: Chemistry of alkaloids, steroids, terpenes, carbohydrates, amino acids, peptides and nucleic acids. ***Aromatic and Heterocyclic Chemistry***: Monocyclic, bicyclic and tricyclic aromatic hydrocarbons, and monocyclic compounds with one hetero atom: synthesis, reactivity and properties.

			INORGANIC CHEMISTRY ***Periodic Table***: Periodic classification of elements and periodicity in properties; general methods of isolation and purification of elements. ***Chemical Bonding and Shapes of Compounds***: Types of bonding; VSEPR theory and shapes of molecules; hybridization; dipole moment; ionic solids; structure of NaCl, CsCl, diamond and graphite; lattice energy. ***Concepts of Acids and Bases:*** Bronsted and Lewis acids and bases; Gas phase versus solution phase acidity; solvent levelling effects; hardness and softness. ***Oxidation and Reduction:*** Redox potentials; Nernst equation; influence of complex formation; precipitation; change of pH and concentration on redox potentials; analysis of redox cycles; redox stability in water; disproportionation/ comproportionation. ***Main Group Elements (s and p blocks)***: General concepts on group relationships and gradation in properties; structure of electron deficient compounds involving main group elements. ***Transition Metals (d block)***: Characteristics of 3d elements; oxide, hydroxide and salts of first row metals; coordination complexes: structure, isomerism, reaction mechanism and electronic spectra; VB, MO and Crystal Field theoretical approaches for structure, color and magnetic properties of metal complexes; organometallic compounds having ligands with back bonding capabilities such as metal carbonyls, carbenes, nitrosyls and metallocenes; homogenous catalysis. ***Bioinorganic Chemistry*****:** Essentials and trace elements of life; basic reactions in the biological systems and the role of metal ions, especially Fe^{2+}, Fe^{3+}, Cu^{2+} and Zn^{2+}; structure and function of hemoglobin and myoglobin and carbonic anhydrase. ***Instrumental Methods of Analysis***: Basic principles; instrumentations and simple applications of conductometry, potentiometry and UV-vis spectrophotometry. **Analytical Chemistry**: Principles of qualitative and quantitative analysis; acid-base, oxidation-reduction and complexometric titrations using EDTA; precipitation reactions; use of indicators; use of organic reagents in inorganic analysis.
3		Mathematics – MATM (237)	**Set Theory and related topics:** Elementary set theory, Finite, countable and uncountable sets, Equivalence relations and partitions **Real Numbers, Sequences and Series:** Real number system as a complete ordered field, Archimedean property, supremum, infimum, Sequence of real numbers, convergence of sequences, bounded and monotone sequences, convergence criteria for sequences of real numbers, Cauchy sequences, subsequences, Bolzano-Weierstrass theorem. Series of real numbers, absolute convergence, tests of convergence for series of positive terms - comparison test, ratio test, root test, Leibniz test for convergence of alternating series **Real Analysis**: Interior points, limit points, open sets, closed sets, bounded sets, connected sets, compact sets. Power series (of a real variable), Taylor's series, radius and interval of convergence, term-wise differentiation and integration of power series **Functions of One Real Variable**: Limit, continuity, intermediate value property, differentiation, Rolle's Theorem, mean value theorem, L'Hospital rule, Taylor's theorem, maxima and minima **Functions of Two and Three Real Variables**: Limit, continuity, partial derivatives, differentiability, maxima and minima **Integral Calculus**: Integration as the inverse process of differentiation, definite integrals and their properties, fundamental theorem of calculus. Double and triple integrals, change of order of integration, calculating surface areas and volumes using double integrals, calculating volumes using triple integrals **Vector Calculus**: Scalar and vector fields, gradient, divergence, curl, line integrals,

			surface integrals, Green, Stokes and Gauss theorems **Group Theory**: Groups, subgroups, Abelian groups, non-Abelian groups, cyclic groups, permutation groups, normal subgroups, Lagrange's Theorem for finite groups, group homomorphism and basic concepts of quotient groups, Cayley's theorem, class equations **Linear Algebra**: Finite dimensional vector spaces, linear independence of vectors, basis, dimension, linear transformations, matrix representation, range space, null space, rank-nullity theorem. rank and inverse of a matrix, determinant, solutions of systems of linear equations, consistency conditions, eigenvalues and eigenvectors for matrices, Cayley-Hamilton theorem, Inner product spaces, Orthonormal basis **Miscellaneous:** Logical reasoning, elementary combinatorics, divisibility in Integers, Congruence, Chinese remainder theorem, Euler's φ-function

Ph.D.

Sl. No.	Name of Centre	Sub. Code & Sub. Code Number	Syllabus for Entrance Examination
1	School of Physical Sciences (SPS)	Mathematical Sciences – MATH (897)	**Analysis:** The structure of the real numbers as an ordered field with the least upper bound property, archimedean property, Bolzano-Weierstrass theorem, Heine-Borel theorem, extended real number system, complex field, Euclidean spaces. Definition and examples of metric spaces, completeness, compactness, connectedness, continuous functions and related properties. Convergence of sequences in a metric space, subsequences, Cauchy sequences. Limits of functions, continuity of functions, uniform continuity, continuity and compactness, continuity and connectedness. Pointwise and uniform convergence, uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, equicontinuity, Arzela-Ascoli theorem, Stone-Weierstrass theorem. Differentiation of functions of several real variables (directional derivatives, partial derivatives, differentiability and the total derivative, chain rule, Jacobian, higher derivatives, interchange of the order of differentiation, Taylor's theorem), inverse function theorem, implicit function theorem, rank theorem, differentiation of integrals. Lebesgue meausre and Lebesgue integral, convergence Theorems. **Linear Algebra:** Vector Spaces, subspaces, linear independence, bases, dimension, algebra of linear transformations, rank-nullity theorem, dual spaces, double dual, eigenvalues and eigenvectors, characteristic polynomial and minimal polynomial, Cayley-Hamilton theorem. Diagonalizability and digonalization, primary decomposition theorem, generalized eigenvectors, Jordan canonical form, rational canonical form. Bilinear forms, symmetric and skew-symmetric bilinear forms, groups preserving bilinear forms, reduction and classification of bilinear forms. **Algebra:** Definition and examples of groups - dihedral, symmetric and permutations groups, matrix groups such as GL(n) , SL(n) , abelian and cyclic groups, subgroups, normal subgroups, quotient groups, centralizer and normalizer of a group, Lagrange's theorem, isomorphism theorems, group actions, class equation, counting orbits, Cayley's theorem, Sylow's theorems, simplicity of alternating groups. Rings and subrings, isomorphisms, ideals, prime and maximal ideals, quotient rings, polynomial rings, unique factorization domain, principal ideal domain, Euclidean domain, Gauss's lemma, irreducibility criteria.

			Definition and examples of fields, extension of fields, finite and infinite extensions, algebraic and transcendental extensions, homomorpshims, isomorphisms and automorphisms, separable and normal extensions, splitting field of a polynomial, extending field morphisms, algebraic closure of a field, finite fields, cyclicity of the mulitplicative group of a finite field, Galois theory. **Complex Analysis:** Algebra of complex numbers, conjugates, modulus, argument, roots. Continuity and derivative of a function of one complex variable, holomorphic functions, Cauchy-Riemann equations, harmonic functions. Polynomial and rational functions, transcendental functions such as exponential, trigonometric and hyperbolic functions, logarithm. Paths and contours, contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, fundamental theorem of algebra, maximum modulus principle, open mapping theorem, Schwarz's lemma, Taylor series and Laurent series. Classification of singularities, orders or zeros and poles, winding number, meromorphic functions, Cauchy's residue theorem, computation of definite integrals using residue theorem, argument principle. Linear fractional transformations, conformal mappings. **Topology:** Definition and examples of topological spaces, basis and subbasis of a topological space, subspace topology, limit points, closure and interior, continuous functions, homeomorphisms, product topology, metric topology, quotient map and quotient topology. Connectedness, path-connectedness, compactness, local compactness and one point compactification. First and second countable spaces, separable spaces, separation axioms, Urysohn lemma, Tietze extension theorem, Tychonoff theorem and Stone-Čech compactification. **Functional Analysis:** Examples of normed spaces (sequence spaces: c, c0, lp spaces; function spaces: C[0, 1], C(R), Lp ([0, 1]), Lp(R)), finite dimensional normed spaces, continuous linear maps, Hahn-Banach Theorem, Hilbert spaces, inner product, linear functionals, orthonormal sets. **Research Methodology:** Elementary set theory, finite, countable and uncountable sets, logic, relations and functions, axioms. Elementary combinatorics, combinatorial probability, pigeon-hole principle, inclusion-exclusion principle. **Miscellaneous Topics:** Fundamental theorem of arithmetic, divisibility, congruences, Chinese remainder theorem, Euler's totient function, primitive roots.

2		Physical Sciences – PHYH (898)	**I. Mathematical Physics** Linear vector spaces. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order. Special functions. Partial differential equations. Green's function. Fourier and Laplace transforms. Complex analysis: analytic functions, poles and residues, series expansion, and evaluation of integrals. **II. Classical Mechanics** Lagrangian and Hamiltonian formalism. Equations of motion. Central force problem. Conservation laws. Small oscillations and normal modes. Special theory of relativity. **III. Electromagnetic Theory** Gauss's law. Laplace and Poisson equations, boundary value problems. Ampere's law. Electromagnetic induction. Maxwell's equations. Scalar and vector potentials. Gauge invariance. Conservation laws for electromagnetic fields. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction of electromagnetic waves. Dynamics of charged particles in static and uniform electromagnetic fields. **IV. Quantum Mechanics** Wavefunctions and operators. Heisenberg uncertainty principle. Schrödinger equation (time-dependent and time-independent). Eigenvalue problems (particle in a box, harmonic oscillator, hydrogen atom). Tunneling. Orbital and spin angular momenta. Addition of angular momenta. Time-independent perturbation theory. Variational method. Time dependent perturbation theory: Fermi's golden rule and selection rules. Identical particles and indistinguishability. **V. Thermodynamics and Statistical Physics** Laws of thermodynamics and their consequences. Thermodynamic potentials. Legendre transformation. Maxwell relations. Chemical potential, phase equilibria. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Blackbody radiation and Planck's distribution. First- and second-order phase transitions. **VI. Atomic & Molecular Physics** Quantum states of electrons in an atom. Relativistic corrections of atomic energy levels. LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Magnetic resonance. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. **VII. Condensed Matter Physics** Bravais lattices. Reciprocal lattice. Diffraction and structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory of metals and electronic specific heat. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Band theory of solids: metals, insulators and semiconductors. Superconductivity: type-I and type-II superconductors. Magnetism: types of magnetic ordering and Curie-Weiss law. **VIII. Nuclear and Particle Physics** Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nuclear force. Single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha,

			beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions. Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). **IX. Electronics** Semiconductor devices (diodes, junctions, transistors, and field effect devices), device characteristics. Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similar circuits). **X. Research Methodology and Experimental Methods** Data analysis. Error estimation. Measurement of electrical resistivity, Hall coefficient, magnetic susceptibility and thermal conductivity. Interference and diffraction experiments. Spectroscopic measurements such as Zeeman effect, Electron Spin Resonance, and Raman effect. Experimental determination of fundamental constants such as Planck's constant, e/m, and Boltzmann constant.
3		Chemical Sciences – CHEH (899)	**Research Methodology** Analytical chemistry, chromatographic separation, crystallization, spectroscopic techniques, electro-and thermoanalytical methods. Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient. **Organic Chemistry** 1. IUPAC nomenclature of organic molecules including regio - and stereoisomers. 2. Principles of stereochemistry: Configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, enantioselectivity, diastereoselectivity and asymmetric induction. 3. Aromaticity: Benzenoid and non - benzenoid compounds – generation and reactions. 4. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes. 5. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species. Determination of reaction pathways. 6. Common named reactions and rearrangements – applications in organic synthesis. 7. Organic transformations and reagents: Functional group interconversion including oxidations and reductions; common catalysts and reagents (organic, inorganic, organometallic and enzymatic). Chemo, regio and stereoselective transformations. 8. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups. 9. Asymmetric synthesis: Chiral auxiliaries, methods of asymmetric induction – substrate, reagent and catalyst controlled reactions; determination of enantiomeric and diastereomeric excess; enantio-discrimination. Resolution – optical and kinetic. 10. Pericyclic reactions – electrocyclisation, cycloaddition, sigmatropic rearrangements and other related concerted reactions. Principles and applications of photochemical reactions in organic chemistry. 11. Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S). 12. Chemistry of natural products: Carbohydrates, proteins and peptides, fatty

			acids, nucleic acids, terpenes, steroids and alkaloids. Biogenesis of terpenoids and alkaloids. 13. Structure determination of organic compounds by IR, UV - Vis, ^{1}H & ^{13}C NMR and Mass spectroscopic techniques. **Inorganic Chemistry** 1. Chemical periodicity: Classification of elements and periodicity in properties. 2. Molecular Structure and Bonding: Valence bond theory, molecular orbital Theory, VSEPR theory. 3. Acids and Bases: Lewis acids and bases, HSAB concept, Gas phase versus solution acidity, Solvent levelling effects, Surface acidity. 4. Oxidation and Reduction: Analysis of redox cycles, Redox stability in water, Disproportionation/Comproportionation, Frost, Latimer and Pourbaix diagrams. 5. Main group elements and their compounds: Allotropy, synthesis, structure and bonding, industrial importance of the compounds. 6. Transition elements and coordination compounds: structure, bonding theories, spectral and magnetic properties, reaction mechanisms. 7. Inner transition elements: spectral and magnetic properties, redox chemistry, analytical applications. 8. Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis. 9. Cages and metal clusters. 10. Bioinorganic chemistry: photosystems, porphyrins, metalloenzymes, oxygen transport, electron-transfer reactions; nitrogen fixation, metal complexes in medicine. 11. Nuclear chemistry: nuclear reactions, fission and fusion, radio- analytical techniques, activation analysis, principles of determination of age of rocks and minerals, and Radio-carbon dating. 12. Characterisation of inorganic compounds by IR, Raman, NMR, EPR, Mössbauer, UV-vis, NQR, MS, electron spectroscopy and microscopic techniques. **Physical Chemistry** 1. Basic principles of quantum mechanics: Postulates; operator algebra; exactly-solvable systems: particle-in-a-box, harmonic oscillator and the hydrogen atom, including shapes of atomic orbitals; orbital and spin angular momenta; tunnelling. 2. Approximate methods of quantum mechanics: Variational principle; perturbation theory up to second order in energy; applications. 3. Atomic structure and spectroscopy; term symbols; many-electron systems and

			antisymmetry principle. 4. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated π-electron systems. 5. Chemical applications of group theory; symmetry elements; point groups; character tables; selection rules. 6. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities – selection rules; basic principles of magnetic resonance. 7. Chemical thermodynamics: Laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria; temperature and pressure dependence of thermodynamic quantities; Le Chatelier principle; elementary description of phase transitions; phase equilibria and phase rule; thermodynamics of ideal and non-ideal gases, and solutions. 8. Statistical thermodynamics: Boltzmann distribution; kinetic theory of gases; partition functions and their relation to thermodynamic quantities–calculations for model systems. 9. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye-Huckel theory; electrolytic conductance – Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations. 10. Chemical kinetics: Empirical rate laws and temperature dependence; complex reactions; steady state approximation; determination of reaction mechanisms; collision and transition state theories of rate constants; unimolecular reactions; enzyme kinetics; salt effects; homogeneous catalysis; photochemical reactions. 11. Colloids and surfaces: Stability and properties of colloids; isotherms and surface area; heterogeneous catalysis. 12. Solid state: Crystal structures; Bragg's law and applications; band structure of solids. 13. Polymer chemistry: Molar masses; kinetics of polymerization.