JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

Syllabus for Pre-Ph. D Examination

Mathematics

PAPER – II		Subject Code
S. No	**Subject**	
1	Universal Algebra	**1309101**
2	Semi Groups	**1309102**
3	Mathematical Modeling through ordinary and partial differential equations	**1309103**
4	Fluid mechanics, heat transfer &magneto gas dynamics	**1309104**
5	Mathematical Statistics	**1309105**
6	Queuing Theory	**1309106**
7	Tensor Calculus	**1309107**

PAPER – III		Subject Code
S. No	**Subject**	
1	Boolean Algebra	**1309201**
2	Lattice Theory	**1309202**
3	Mathematical theory of Elasticity	**1309203**
4	Boundary value problems	**1309204**
5	Ultrasonic Waves in Elastic media	**1309205**
6	Operations Research	**1309206**
7	Non-linear Functional analysis	**1309207**
8	Relativity and Cosmology	**1309208**

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Mathematics

PAPER – II

Universal Algebra

1. Definitions of Lattices – Isomorphic lattices and Sublattices – Distributive and Modular Lattices – Complete Lattices, Equivalences and Algebraic Lattices – Closure Operators.

2. Definitions and Examples of Algebras – Isomorphic Algebras and Subalgebras – Algebraic Lattices and Subuniverses – The Irredundant basis theorem – Congruences and Quotient Algebras – Homomorphisms and the Homomorphism and Isomorphism theorems.

3. Direct Products, Factor congruneces and Directly indecomposable algebras – Subdirect products, subdirectly irreducible algebras and simple algebras – Class operators and Varieties – Terms, Term algebras and Free algebras – Identities, Free algebras and Birkhoff Theorem – Malcev Conditions.

4. Boolean algebras – Boolean rings – Filters and Ideals – Stone Duality – Boolean Powers – Ultra products and congruences.

5. Distributive varieties – Primal algebras – Boolean products – Discriminator varieties – Quasiprimal algebras Functionally complete algebras and Skew free varieties.

Prescribed book:
A Course in Universal Algebra by Stanley Burris and H.P. Sankappanavar, Springer Verlag Publications.

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Mathematics

Semi Groups

1. Preliminaries: Introduction, Definition of a Semigroup, Special subjects of Semigroups, Special elements of a semigroup, Relations and Functions on a Semigroup, Examples
   (Chapter 1 of Textbook)
2. Semilattice Decompositions: Subdirect Products, Completely Prime ideals and filters, Completely Semiprime ideal and π- subjects, Semilattices of simple Semigroups, Weakly commutative Semigroups, Separative semigroups, π-Semigroups
   (Chapter 2 of Textbook)
3. Ideal Extenstions: Extensions and Translations, Extensions of a weakly reductive Semigroup, Strict and pure extensions, Retract extensions, Dense extensions, Extenstinos of an arbitrary Semigroup, Semillatice Composistions,
4. Completely Regular Semigroups: Generalities, Completely simple Semigroups, Semillatices of rectangular groups, Strong Semilattices of a completely simple Semigroups, Subdirect Products of a Semilattice and a Completely simple Semigroup.
   (Chapter 4 of Textbook)

Prescribed book:

Introduction to Semigroups, Mario Petrich, Charles E. Merrill publishing Company, A Bell & Howell Company, Columbus, Ohio.

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Mathematics

Mathematical Modeling through ordinary and partial differential equations

UNIT I (Mathematical Modelling Through Systems of Ordinary Differential Equations of the First Order):
Mathematical Modelling in Population Dynamics-Epidemics -Compartment Models - Economics -Medicine, Arms Race, Battles and International Trade in Terms of Systems of Ordinary Differential Equations.

UNIT II (Mathematical Modelling Through Ordinary Differential Equations of Second Order):
Mathematical Modelling of Planetary Motions, Circular Motion and Motion of Statellites- Mathematical Modelling Through Linear Differential Equations of Second Order.

UNIT III (Mathematical Modelling Through Difference Equations):
The Need for Mathematical Modelling Through Difference Equations: Some Simple Models, Basic Theory of Linear Difference Equations with Constant Coefficients, Mathematical Modelling Through Difference Equations in Economics and Finance- Population Dynamics and Genetics- Probability Theory- Miscellaneous Examples of Mathematical Modelling Through Difference Equations.

UNIT IV (Mathematical Modeling through Partial Differential Equations):
Situations Giving Rise to Partial Differential Equations Models, Mass-Balance Equations: First Method of Getting PDE Models, Momentum-Balance Equations: The Second Method of Obtaining Partial Differential Equation Models, Variational Principles: Third Method of Obtaining Partial Differential Equation Models, Probability Generating Function, Fourth Method of Obtaining Partial Differential Equation Models, Model for Traffic Flow on a Highway, Nature of Partial Differential Equations, Initial and Boundary Conditions.(Chapters 1 to 6 of Text Book 1)

UNIT V (Perturbation Techniques):
Classical Perturbation Techniques. Introduction, The Fundamental Technique, lagrange Expansion, Multidimensional lagrange Expansion, Linear Differential Equations, Linear Equations with almost Constant Coefficients, Inhomogeneous Linear Equations, Linear Perturbation Series – I, Linear Perturbation Series-II, Two Point Boundary Value Problems, Perturbation Techniques –I, Perturbation Techniques-II, Perturbation in General, Invariant Imbedding, Multidimensional Considerations, The Matrix Exponential, Variable Coefficients, Baker-Campbell - Hausdirff Series, Non Linear Perturbation, Poincare-Lyapunav Theorem, Asymptotic Behavior.

Periodic Solutions of Nonlinear Differential Equations and Renormalization Techniques. Introduction, Secular Terms, Renormalization a la Lindstedt, The Van der Pol Equation, The Shohat Expansion, Perturbation Series for the period, Self-consistent Techniques, Carleman Linearization.(Articles 1-23 of part1,Articles 1-8 of part 2 of Text Book 2)

Text Books: 1) Mathematical Modelling by J.N.Kapur, Wiley Eastern Ltd.
2) Perturbation Techniques in Mathematics, Physics and Engineering by Richard Bellman, Holt, Rinehart and Winston, Inc.

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Mathematics

Fluid mechanics, heat transfer and magneto gas dynamics

UNIT-I

Basic concepts of Fluid Mechanics and Heat transfer: Fundamentals of fluid flow and Heat transfer in viscous fluids. Derivation of Navier-Stoke's equation of motion of viscous fluids, Limitations of the Navier-Stoke's equations, Equation of energy, Equation of vorticity

UNIT II

Exact solutions for geometries of steady flow between two parallel plates, Plane Couette flow, Plane Poiseulle flow, Generalized plane Couette flow, Flow between two porous plates , unsteady flow over a flat plate, Unsteady flow between two parallel plates.

UNIT III

Boundary layer concept. The entrance region in conduits - Laminar flow and heat transfer in tubes.

UNIT-IV

Similarity methods in laminar flow-Integral methods- Reynolds analogy. Free convection on vertical surfaces and from horizontal surfaces. Heat transfer. Speed of sound Mach number and flow regimes. Shock waves, Flow along a flat plate. Fundamental equations: Maxwell's equations-Laminar flow between parallel plates /flow in a pipe under external magnetic filed.

UNIT V

Stability of magnetic gas dynamic flows. Stability of laminar flow between parallel planes in the presence of a coplanar magnetic field and under a transverse magnetic field. Stability of boundary layer flow.

TEXT BOOKS:

1. Introduction to Fluid mechanics and Heat transfer by J.D.Parker, J.H.Boggs and Edward F.Blick, Addission Wesley Publishing Co.1969 (Relevant portions only).
2. Foundations of Fluid Mechanics by S.W.Yaan, Prentice- Hall, Inc. Englewood Cliffs, New Jersey (Relevant topics only).
3. Magneto Gas dynamics and Plasma dynamics by Smith I Pai-Springer Verlag, 1962 (Relevant topics only)

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Mathematics

Mathematical Statistics

Conditional Probability And Stochastic Independence : Conditional Probability-Marginal and conditional distributions - The Correlation Coefficient – Stochastic Independence.

Distributions Of Functions Of Random Variables : Sampling theory-Transformation of variables of the discrete type – Transformation of variables of the continuous type – The t and F distributions – Extensions of the change-of-variable technique – Distributions of order statistics – The Moment-Generating-Function Technique – The distributions of $\bar{X}$ and ns^2/σ^2 – Expectations of functions of random variables.

Limiting Distributions : Limiting distributions – Stochastic convergence – Limiting moment-generating functions – The central limit theorem – Some theorems on limiting distributions.

Other statistical tests : Chi-square tests – The distributions of certain quadratic forms – A test of equality of several means – Noncentral χ^2 and Noncentral F – The Analysis Of Variance – A Regerssion Problem – A Test Of Stochastic Independence.

NonParametric Methods : Confidence intervals for distribution quantiles – Tolerance limits for distributions – The Sign Test – A test of Wilcoxon – The equality of two distributions – The Mann-Whitney-wilcoxon test – Distributions under Alternative Hypothesis – Linear Rank Statistics.

Text Book:

Mathematical Statistics, Hogg and Craig, Pearson Edn., New Delhi.

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Mathematics

Queuing Theory

Introduction, Poisson process and the exponential distribution, Markovian property of the exponential distribution, Stochastic processes and Markov chains, Steady state birth-death processes. (Sec. 1.1 to 1.10 of the text book)**.**

Simple Markovian Birth-Death queueing models: Steady state solution for the M/M/1 models, Methods of solving steady state difference equations, Queues with parallel channels, Queues with parallel channel and truncation, Erlang formula, Queues with unlimited service. (Sec. 2.1 to 2.6 of the text book)

Finite source queues, State dependent service, Queues with impatience, busy period analysis for M/M/1 and M/M/c queues. (Sec. 2.7 to 2.9 and Sec 2.10 of the text book)

Advanced Markovian queueing models: Bulk-input, Bulk-service, Erlangian Models, Priority queue disciplines (Sec. 3.1 to 3.4 of the text book).

Models with general arrival and service patterns: Single server queues with Poisson input and general service, Multi-server queues with Poisson input and general service, General input and exponential service (Sec. 5.1 to 5.3 of the text book).

Text: Fundamentals of Queueing Theory, Donald Gross and Carl M. Harris, Third Edition, John Wiley & Sons, Inc, New York.

Reference Books:

1) Stochastic Processes, J. Medhi, New Age International Publishers, Second Edition.
2) Operations Research, Hamdy A. Taha, Prentice-Hall of India, Eighth Edition.

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Mathematics

TENSOR CALCULUS

Unit-1:

Tensor Algebra: Introduction, N-Dimensional space, Transformation of coordinates, Indicial and summation conventions, Contravariant vectors, Covariant vectors, Invariants, Second order tensors, Higher order tensors, Addition ,subtraction , and multiplication of tensors, contraction, Quotient law, Conjugate symmetric tensors of the second order.

UNIT-2

The Line Element: Fundamental tensor, Length of a curve, Magnitude of a vector, Associate tensors, Angle between two vectors-Orthogonally, Principal directions.

UNIT-3

Covariant Differentiation: Christoffel symbols, Transformation law of Christoffel symbols, Covariant differentiation of vectors, Covariant differentiation of tensors, Laws of covariant differentiation, Intrinsic derivatives.

UNIT-4

Geodesics-Parallelism: Geodesics, Null-Geodesics, Geodesic coordinates, Parallelism, Covariant derivative.

UNIT-5

Curvature Tensor: Riemann-Christoffel tensor, Curvature tensor, Ricci tensor-Curvature invariant, Bianchi's identity, Riemannian Curvature, Flat space, space of constant curvature.

UNIT-6

Cartesian Tensors: Orthogonal transformations, Rotations, Cartesian tensors, Infinitesimal strain, Stress, Equations of equilibrium, Generalized Hooke's law, isotropic tensors, Homogeneous and isotropic body, Curvilinear coordinates, Mechanics of continuous matter.

TEXT BOOK:

1. Bary Spain, Tensor Calculus-Radha Publishing House,Calcutta

REFERENCE BOOKS:

1. Tensor Calculus, J.L.Synge and A.Schild, University of Toronto Press, Toronto.
2. Tensor Calculus, A.K.Agarwal, Krishna Prakasam mandir, Meerut.
3. Riemannian Geometry by L.P.Eisenhart, Princeton University Press, Princeton 1966.

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Mathematics

PAPER - III

Boolean Algebra

Boolean rings – Boolean algebras – Fields of sets - Elementary relations- Order – Infinite operations – Subalgebras – Homo morphisms- Free Algebras- Ideals and filters – The Homo morphisms theorem- Boolean o-algebras- The countable chain condition – Measure algebras - Atoms – Boolean spaces – The representation theorem -Duality for ideals – Duality for Homo morphisms.

Reference Book:

Lectures on Boolean Algebras, by Paul R. Halmos, D. Van Nostrand Company, Inc. Princeton, New Jersey.

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Mathematics

Lattice Theory

Unit – I:
Two Definitions of Lattices, How to Describe Lattices, Some Algebraic Concepts, Polynomials, Identities and Inequalities (Section 1, 2, 3, & 4 of Chapter – I of Prescribed Text Book)

Unit – II:
Free Lattices, Special Elements, Characterization Theorems and Representation Theorems, Congruence Relations (Sections 5.6 of Chapter – I & Sections 1, 2, 3 of Chapter – II of prescribed Text Book)

Unit – III
Boolean Algebras R – generated by Distributive Lattices, Topological Representation, Distributive Lattices with Pseudo Complementation (Sections 4.5 & 6 of Chapter – II of prescribed Text Book)

Unit – IV:
Weak protectivity and Congruences, Distributive, Standard and Neutral elements, Distributive, Standard and Neutral Ideals, Structure theorems (Sections 1, 2,3, & 4 of Chapter – III of Prescribed Text Book)

Text Book:
General Lattice Theory by George Gratzer, Academic press, New York, 1978.

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Mathematics

Mathematical theory of Elasticity

UNIT I

Deformation: Displacements and Strains-General Deformations-Geometric Construction of Small Deformation Theory-Strain Transformation-Principal Strains-Strain Compatibility

UNIT II

Stress and Equilibrium: Body and Surface Forces-Traction Vector and Stress Tensor-Stress

Transformation-Principal Stresses-Equilibrium Equations

Material Behavior—Linear Elastic Solids: Material Characterization-Linear Elastic Materials—Hooke's Law-Physical Meaning of Elastic Moduli

UNIT III

Formulation and Solution Strategies: Review of Field Equations-Boundary Conditions and Fundamental Problem Classifications-Stress Formulation-Displacement Formulation-Principle of Superposition-Saint- Venant's Principle

UNIT IV

Anisotropic Elasticity: Basic Concepts-Material Symmetry-Restrictions on Elastic Moduli-Torsion of a Solid Possessing a Plane of Material Symmetry-plane deformation problems-application to fracture mechanics.

UNIT V

Displacement Potentials and Stress Functions: Helmholtz Displacement Vector Representation-Lame´s. Strain Potential- Galerkin Vector Representation-Papkovich-Neuber Representation

Text Book:

1. Martin H Sadd, Elasticity-Theory, Application and Numerics, Academic Press 2nd Edition

(Chapter 2-2.1,2.2,2.3,2.4,2.6. Chapter 3-3.1,3.2,3.3,3.4,3.6
Chapter4-4.1,4.2,4.3; Chapter5- 5.1,5.2,5.3,5.4,5.5,5.6
Chapter11-11.1,11.2,11.3,11.4 , 11.5,11.6 Chapter 13-13.1,13.2,13.3,13.4

References:

1.A.E.H.Love " A treatise on the mathematical theory of Elasticity" 4th Edition, Dover
Publications

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Mathematics

Boundary value problems

UNIT – I

General theory for linear first order system of differential equations, Existence of solutions, Solution space. The first order non-homogeneous equation, variation of parameters. The adjoint nth order equation. Relation between scalar and vector adjoints.

UNIT – II

The two point boundary value problems, Homogeneous two-point boundary value problems, the adjoint boundary problem, the non-homogeneous boundary problem, Green's matrix and self – adjoint boundary value problem.

UNIT – III

Introduction to Eigen value problems, the vibrating string problem, Heat conduction problem, properties of the Green's operator. Existence of Eigen values and Eigen functions.

UNIT IV

Non – linear boundary value problems, kinds of boundary value problems, the Generalized Lipschitz condition, failure of existence and uniqueness to Linear boundary value problem, relation between first and second boundary value problems. A more general Lipschitz condition, application to boundary value problems (Chapters 1,2, and 3 of Ref. 4).

UNIT – V

Stability: Definition and examples Liapunov method for uniform stability, Asymptotic stability. Linear and quasi-linear ordinary differential systems, Autonomous Ordinary differential systems, trajectories and critical points, linear systems of second order, critical points of quasi-linear systems of second order.

Books:

1. Theory of Ordinary and delay differential equations by R.D. Driver Kingston R.I., Nov,
1976(Springs Verlag)
2. Theory of ordinary differential equations by E.A. coddington and N. Levinson.
3. Theory of ordinary differential equations by R.H. Cole, appleon century – crofts, New
York, 1968.
4. Non-Linear two point boundary value
Problems by P.B. Bailey, L.F. Shampine and P.E. Waltman, Academic press, New York, London (1968)

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Mathematics

Ultrasonic Waves in Elastic media

UNIT I

Dispersion Principles-Waves in a taut string-Governing equation and solutions-String on an elastic base, viscous foundation, viscoelastic foundation- Graphical representation of dispersive systems- Group Velocity concepts

UNIT II

Reflection and refraction- Normal beam incidence reflection factor –Snell's law – Critical Angles and Mode conversion- Oblique incidence-Reflection and transmission factors for interfaces between two semi-infinte media-solid-solid boundary conditions-solid-liquid boundary conditions-Solid layer embedded between two solids with imperfect boundary conditions-propagator matrix-reflection and transmission coefficients-numerical computation.

UNIT III

Waves in plates-Free plate problem- Solution by method of potentials and partial wave techniquenumerical solution-group velocity-wave structure analysis-waves in rods-longitudinal waves in thin rodslongitudinal, torsional, flexural waves in an infinte solid cylindrical rod

UNIT IV

Waves in hollow cylinders-circumferential guided modes in elastic hollow cylinder-longitudinal guided modes-longitudinal axisymmetric modes –longitudinal flexural modes.

UNIT V

Guided waves in multiple layers-N-layered plates-analysis-displacement-strain-tractions-boundary conditions-dispersion equations-special configurations-two layer-three layer-four layered.

Text Book:

Joseph L Rose, Ultrasonic waves in Solid media , Cambridge University Press , 2004 Edition

Sections:2.1 through 2.8 , 4.1 through 4.4, 5.1,5.2,5.3, 8.1 through 8.5, 11.1 through 11.3, 12.1 through
12.5, Sections 13,13.1,13.2

References:

1. I.A.Viktorov, Rayleigh and Lamb Waves: Physical theory and Applications, Plenum Press
2. J.David.N.Cheeke, Fundamentals and Applications of Ultrasonic Waves, CRC Press

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Mathematics

Operations Research

UNIT – I : Linear Programming problem Formation, Graphical solution of Linear Programming problems, General formation of Linear Programming problem, convex set, Extreme points of a Convex set, convex Hull. Linear Programming : Simplex Method, computational procedure of simplex method, Artificial variables Technique, Two phase Method, simple way for two phase simplex method. Big M – Method.

UNIT – II : Method of resolve degeneracy special cases unbounded solutions, Non existing feasible solutions summary of computational procedure of Simplex Method. Revised Simplex Method, Duality in linear programming, Fundamental duality theorem, Existence theorem, The Dual simplex method : Computational procedure of Dual simplex method.

UNIT – III : Transportation modals : Matrix form of transportation problem, feasible solution existence of feasible solution existence of optimal solution, loops in transportation table and their properties, The initial basic in transportation table and their properties, The initial basic feasible solution to Transportation problem, methods for initial Basis feasible solution, Moving towards optimum solution, To examine the initial basic feasible solution for Non- degeneracy, Determination of Net evaluations, the Optimality test, Degeneracy in Transportation problem, Unbalanced transportation problem.

UNIT – IV :Assignment problem : Mathematical formulation of Assignment problem, Fundamental theorems, Hungarian Method for Assignment problem, Assignment Algorithm unbalanced assignment problem. The Maximal Assignment problem, Restrictions on Assignment. Replacement Models : The Replacement problem, Failure Mechanism of items, Replacement policy for items whose maintenance cost increases with time and money value is constant.

Scope as in Operations Research by S.D. Sharma, Kedarnath and Ramnath.

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Mathematics

Non-linear Functional analysis

UNIT I

Banach's contraction mapping principle- Generalization of Banach's contraction theorem; Schauder's theorem for nonexpansive mappings.

UNIT II

Nonlinear alternative of Leray- Schauder type for nonexpansive mappings, Homotopy for contractions, nonlinear alternative of Leray-Schauder type for contractive mappings and their generalizations to nonexpansive mappings, Brouwer's theorem.

UNIT III

Schauder's theorem; Monch's theorem; Applications to a discrete boundary value problem and a second order homogeneous Dirichlet problem (Scope as in Chapters 1,2,3 and 4 of the textbook.)

UNIT IV

Fixed point theory for nonself mappings in Banach spaces; Nonlinear alternative for continuos compact nonself mappings using Schauder's theorem and Monch's theorem; Nonlinear alternatives for κ – set contractive mappings; the essential mapping approach of Granas; the Schauder-Tychonoff theorem;

UNIT V

Fixed point theorems in Conical shells; Krasnosel'skii's theorems; Applications to Fredholm integral equations. (Scope as in Chapters 5,6 and 7 of the textbook.)

TEXTBOOK:

Fixed Point Theory and Applications by R.P.Agarwal, M.Meehan and D.O'Regan, Cambridge Tracts in Mathematics 141, Cambridge University Press 2004.

REFERENCES:

1. An Introduction to Metric Spaces and Fixed Point Theory by M.A.Khamsi and W.A. Kirk, John Wiley & Sons INC, 2001.
2. Nonlinear Functional Analysis by K.Deimling-Verlag 1985.
3. Fixed Point Theory for Lipschitzian-type Mappings with Applications by Ravi P.Agarwal, Donal O'Regan, and D.R.Sahu, Volume 6, Springer 2009.
4. Handbook of Topological Fixed Point Theory by R.F.Brown, M.Furi, L.Gorniewicz and B.Jiang, Springer 2005.

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Mathematics

RELATIVITY AND COSMOLOGY

Special theory of Relativity:

UNIT-1:

Lorentz Transformation: The new concepts of space and time, Postulates of special theory of relativity, Lorentz transformation equations, Lorentz and Fitzgerald contraction, Time dilation or apparent retardation of rest, An interesting example of time dilation, Simultaneity, Relativistic formulae for composition of velocities and acceleration, Proper time, Lorentz transformations form a group, Problems related to time delation, problems related to Lorentz contraction, Problems related to composition of velocities, problems related to Lorentz invariance.

UNIT-2:

Relativistic Mechanics: Mass and momentum, Newton's laws of motion, Measurement of different units, Experimental verification of $m=m_0/\text{sqrt}(1-v^2/c^2)$, Equivalence of mass and energy, Transformation formula of mass, Transformation formula for momentum and energy, Transformation formulae for force, Relativistic transformation formula for density, Minkowski space, Geometrical interpretation of lorentz transformation, space and time like intervals, World points and World lines, Light cones, proper times, Energy momentum four vector, Relativistic equation of motion, Minkowski's equation of motion.

General theory of relativity:

UNIT-3:

Relativistic field equations: Introduction to general theory, Principle of Covariance, Principle of equivalence, Energy momentum tensor, Field equations, Poisson's equation as an approximation of field equations, Derivation of field equations from lagrangian density, Equality of inertial and gravitational mass.

UNIT-4:

Schwarzschild solution: Einstein's law of gravitation in empty space, Schwarzschild exterior solution, Brickhoff's theorem, Relation between M and m, Isotropic co-ordinates, Planetary orbits, Advance of perihelion, Gravitational shift of spectral lines, schwarzschild's interior solution.

UNIT 5:

Cosmology: Cosmological models, Einstein and de-sitter line elements, Properties of Einstein universe, Properties of de-sitter's universe, Comparison of Einstein model with actual universe, Comparison of de-sitter model with actual universe, Co-moving co-ordinates systems, Derivation of the R-W line element.

UNIT-6

Einstein Maxwell Theory: Some theorems, Gauge Transformation, Transformation equations for differential operators, Transformations equations for E and H, Maxwell's equations are invariant, some theorems, Equation of continuity, Lorentz Condition, Electromagnetic energy momentum tensor, Law of gravitation in electromagnetic field, Energy and momentum of the electromagnetic field, Electromagnetic stress, Gravitational field due to an electron at rest, Equations of a charged particle, Lagrangian for a charged particle.

Text Books:

1.Theory of Relativity by S.R.Roy and Raj bali ,Jaipur Publishing House, Jaipur.
2. J.K.Goyal and K.P.Gupta, theory of Relativity, Krishna Prakasam media(p)Ltd,Meerut.

Reference Books:

1. Special Relativity, W.RINDLER, Oliver and Boyd Ltd.
2. Fundamentals of special and General Relativity, K.D.Krori, PHI Learning private Ltd, New Delhi.
3. Relativity ,Thermo Dynamics and Cosmology, R.C .Tolman, Oliver and Boyd Ltd.