Center for Basic Sciences
(CBS)
COURSE STRUCTURE
SCHEME OF EXAMINATION
Learning Outcome
&
Syllabus
Of
Five year
M.Sc. Integrated (Physics Stream)

UNDER

FACULTY OF SCIENCE

Approved by Board of Studies in Physics

Session 2023-2028

Center for Basic Sciences
Pt. Ravishankar Shukla University
Raipur (C.G.) 492010
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WEBSITE:- https://prsu.ac.in/academic-departments/utd-departments/Center-for-Basic Sciences-CBS/68

Course structure of
Five Year M. Sc. Integrated (Physics Stream)
Session 2023 - 28

- Minimum total credits for integrated M.Sc. degree is 240.
- Semesters I to VIII will carry 25 credits each.
- Semesters IX and X will carry 20 credits each.

Abbreviation: **B**: Biology, **C**: Chemistry, **M**: Mathematics, **P**: Physics, **G**: General, **H**: Humanities, **BL**: Biology Laboratory, **CL**: Chemistry Laboratory, **PL**: Physics Laboratory, **GL**: General Laboratory, **PE**: Physics Elective, **PPr**: Physics Project

FIRST YEAR

SEMESTER -I

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
B101	Biology - I	[2 + 1]	3
C101	Chemistry - I	[2 + 1]	3
M101/MB101	Mathematics - I	[2 + 1]	3
P101	Introductory Physics - I	[2 + 1]	3
G101	Computer Basics	[2 + 1]	3
H101	Communication Skills	[2]	2
		Contact Hours /Week Laboratory	
BL101	Biology Laboratory - I	[4]	2
CL101	Chemistry Laboratory - I	[4]	2
PL101	Physics Laboratory - I	[4]	2
GL101	Computer Laboratory	[4]	2
	(25 of 240 credits)		**25**
Additional Papers			
ES101	Environmental Studies	[2]	2

SEMESTER -II

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
B201	Biology - II	[2 + 1]	3
C201	Chemistry - II	[2 + 1]	3
M201/MB201	Mathematics-II	[2 + 1]	3
P201	Introductory Physics - II	[2 + 1]	3
G201	Electronics and Instrumentation	[2 + 1]	3
		Contact Hours /Week Laboratory	
BL201	Biology Laboratory - II	[4]	2
CL201	Chemistry Laboratory - II	[4]	2
PL201	Physics Laboratory - II	[4]	2
GL201	Electronics Laboratory	[2]	2
H201	Communication Skills Lab	[4]	2
	(50 of 240 credits)		**25**
Additional Papers			
ES201	Environmental Studies	[2]	2

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SECOND YEAR

SEMESTER - III

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P301	Mathematical Physics - I	[3 + 1]	4
P302	Classical Mechanics - I	[3 + 1]	4
P303	Electromagnetism	[3 + 1]	4
P304	Waves and Oscillations	[3 + 1]	4
H301	Creative Hindi	[2 + 0]	2
H302	History and Philosophy of Science	[2 + 0]	2
		Contact Hours /Week Laboratory	
PL301	Physics Laboratory - III	[6]	3
GL301	Applied Electronics Laboratory	[4]	2
		(75 of 240 credits)	**25**

SEMESTER -IV

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P401	Mathematical Physics - II	[4 + 1]	5
P402	Quantum Mechanics - I	[4 + 1]	5
PCB401	Physical and Chemical Kinetics	[3+1]	4
G401	Statistical Techniques and Applications	[3+1]	4
		Contact Hours /Week Laboratory	
PL401	Physics Laboratory-IV	[6]	3
GL401	Computational Laboratory and Numerical Methods	[4]	2
H401	Communication Skills Lab-II	[4]	2
		(100 of 240 credits)	**25**

THIRD YEAR

SEMESTER - V

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P501	Quantum Mechanics - II	[4 + 1]	5
P502	Classical Mechanics - II	[4 + 1]	5
P503	Atomic and Molecular Physics	[3 + 1]	4
PM501	Numerical Analysis	[3 + 1]	4
H501	Scientific Writing in Hindi	[2]	2
		Contact Hours /Week Laboratory	
PL501	Physics Laboratory - V	[6]	3
PML501	Numerical Methods Laboratory	[4]	2
		(125 of 240 credits)	**25**

SEMESTER - VI

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P601	Electrodynamics	[4 + 1]	5
P602	Statistical Mechanics - I	[4 + 1]	5
P603	Condensed Matter Physics - I	[3 + 1]	4
P604	Lasers	[3 + 1]	4
H601	Ethics of Science and IPR	[2]	2
H602	Scientifc Writing in Einglish	[2]	2
		Contact Hours /Week Laboratory	
PL601	Physics Laboratory - VI	[6]	3
		(150 of 240 credits)	**25**

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FOURTH YEAR

SEMESTER - VII

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P701	Astronomy and Astrophysics - I	$[3+1]$	4
P702	Quantum Mechanics - III	$[3+1]$	4
P703	Statistical Mechanics - II	$[3+1]$	4
P704	Nuclear Physics - I	$[3+1]$	4
	Computational Physics - B (only for students who have already studied Nuclear Physics - I as P602)	$[3+1]$	
		Contact Hours / Week Laboratory	
PL701	Advanced Physics Laboratory - I	[10]	5
PPr701	Reading Project	[8]	4
	(175 of 240 credits)		**25**

SEMESTER - VIII

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
P801	Astronomy and Astrophysics-II	$[3+1]$	4
P802	Fluid Mechanics	$[3+1]$	4
P803	Nuclear and Particle Physics	$[3+1]$	4
P804	Condensed Matter Physics - II	$[3+1]$	4
		Contact Hours / Week Laboratory	
PL801	Advanced Physics Laboratory - II	[10]	5
PPr801	Project	[8]	4
	(200 of 240 credits)		**25**

FIFTH YEAR

SEMESTER- IX

Subject Code	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
PPr901	Project		20
	(220 of 240 credits)		**20**

SEMESTER- X

Subject Code*	Subject	Contact Hours / Week [Theory+Tutorials]	Credits
PE - 1	Quantum Field Theory	$[4+1]$	5
PE - 2	General Relativity and Cosmology	$[4+1]$	5
PE - 3	Experimental Techniques	$[4+1]$	5
PE - 4	CCD Imaging and Spectroscopy	$[4+1]$	5
PE - 5	Biophysics	$[4+1]$	5
PE - 6	Particle Physics	$[4+1]$	5
PE - 7	Nonlinear Dynamics and Chaos	$[4+1]$	5
PE - 8	Reactor Physics and Radiation Science	$[4+1]$	5
PE - 9	Accelerator Physics and Applications	$[4+1]$	5
PE - 10	Computational Physics - C	$[4+1]$	5
PE - 11	Glimpses of Contemporary Sciences	$[4+1]$	5
PE - 12	Earth Science and Energy & Environmental Sciences	$[4+1]$	5
PE - 13	Circuits and Electronics	$[4+1]$	5
	(240 of 240 credits)		**20**

***Four Subjects will be offered according to the availability of instructors and minimum number of interested students taking a course.The chosen four subject will have codes PE1001, PE1002, PE1003 and PE1004.**

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Scheme of examination (Physics Stream)

Integrated M.Sc. Semester – I

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
B101	Biology - I	60	24	40	16	100	3
C101	Chemistry - I	60	24	40	16	100	3
M101/MB101	Mathematics - I	60	24	40	16	100	3
P101	Introductory Physics- I	60	24	40	16	100	3
G101	Computer Basics	60	24	40	16	100	3
H101	Communication Skills	60	24	40	16	100	2
Practical							
BL101	Biology Laboratory-I	60	24	40	16	100	2
CL101	Chemistry Laboratory-I	60	24	40	16	100	2
PL101	Physics Laboratory-I	60	24	40	16	100	2
GL101	Computer Laboratory	60	24	40	16	100	2
Additional Papers							
ES101	Environmental Studies	60	24	40	16	100	2

Integrated M.Sc. Semester – II

Subject Code	Subject	Internal Marks		External Marks		Total Marks	Credit
		Max	Min	Max	Min	Max	
B201	Biology - II	60	24	40	16	100	3
C201	Chemistry - II	60	24	40	16	100	3
M201/MB201	Mathematics-II	60	24	40	16	100	3
P201	Introductory Physics-II	60	24	40	16	100	3
G201	Electronics and Instrumentation	60	24	40	16	100	3
Practical							
BL201	Biology Laboratory- II	60	24	40	16	100	2
CL201	Chemistry Laboratory-II	60	24	40	16	100	2
PL201	Physics Laboratory- II	60	24	40	16	100	2
GL201	Electronics Laboratory	60	24	40	16	100	2
H201	Communication Skills Lab	60	24	40	16	100	2
Additional Papers							
ES201	Environmental Studies	60	24	40	16	100	2

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Integrated M.Sc. Semester – III

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P301	Mathematical Physics - I	60	24	40	16	100	4
P302	Classical Mechanics - I	60	24	40	16	100	4
P303	Electromagnetism	60	24	40	16	100	4
P304	Waves and Oscillations	60	24	40	16	100	4
H301	Creative Hindi	60	24	40	16	100	2
H302	History and Philosophy of Science	60	24	40	16	100	2
Practical							
PL301	Physics Laboratory- III	60	24	40	16	100	3
GL301	Applied Electronics Laboratory	60	24	40	16	100	2

Integrated M.Sc. Semester – IV

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P401	Mathematical Physics-II	60	24	40	16	100	5
P402	Quantum Mechanics- I	60	24	40	16	100	5
PCB401	Physical and Chemical Kinetics	60	24	40	16	100	4
G401	Statistical Techniques and Applications	60	24	40	16	100	4
Practical							
PL401	Physics Laboratory-IV	60	24	40	16	100	3
GL401	Computational Laboratory and Numerical Methods	60	24	40	16	100	2
H401	Communication Skills Lab-II	60	24	40	16	100	2

Integrated M.Sc. Semester – V

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P501	Quantum Mechanics-II	60	24	40	16	100	5
P502	Classical Mechanics-II	60	24	40	16	100	5
P503	Atomic and Molecular Physics	60	24	40	16	100	4
PM501	Numerical Analysis	60	24	40	16	100	4
H501	Scientific Writing in Hindi	60	24	40	16	100	2
Practical							
PL501	Physics Laboratory- V	60	24	40	16	100	5
PML501	Numerical Methods Laboratory	60	24	40	16	100	5

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Integrated M.Sc. Semester – VI

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P601	Electrodynamics	60	24	40	16	100	5
P602	Statistical Mechanics- I	60	24	40	16	100	5
P603	Condensed Matter Physics - I	60	24	40	16	100	4
P604	Lasers	60	24	40	16	100	4
H601	Ethics of Science and IPR	60	24	40	16	100	2
H602	Scientific Writing in English	60	24	40	16	100	2
Practical							
PL601	Physics Laboratory- VI	60	24	40	16	100	3

Integrated M.Sc. Semester – VII

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P701	Astronomy and Astrophysics - I	60	24	40	16	100	4
P702	Quantum Mechanics- III	60	24	40	16	100	4
P703	Statistical Mechanics- II	60	24	40	16	100	4
P704	Nuclear Physics- I Computational Physics-B (only for students who have already studied Nuclear Physics-I as P602)	60	24	40	16	100	4
Practical							
PL701	Advanced Physics Laboratory - I	60	24	40	16	100	5
PPr701	Reading Project	60	24	40	16	100	4

Integrated M.Sc. Semester – VIII

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	Min	Max	Min		
P801	Astronomy and Astrophysics-II	60	24	40	16	100	4
P802	Fluid Mechanics	60	24	40	16	100	4
P803	Nuclear and Particle Physics	60	24	40	16	100	4
P804	Condensed Matter Physics - II	60	24	40	16	100	4
Practical							
PL801	Advanced Physics Laboratory- II	60	24	40	16	100	5
PPr801	Project	60	24	40	16	100	4

Integrated M.Sc. Semester – IX

Subject	Project Report/Dissertation		Seminar Based on Project		Viva-Voce Based on Project Report and Seminar		Total Marks Max	Credit
	Max	**Min**	**Max**	**Min**	**Max**	**Min**		
CPr901-Project	**150**	**60**	**150**	**60**	**100**	**40**	**400**	**20**

Integrated M.Sc. Semester – X

Subject Code	Subject	Internal Marks		External Marks		Total Marks Max	Credit
		Max	**Min**	**Max**	**Min**		
PE1001	**Elective subjects will be offered according to the availability of instructors and minimum number of interested students taking a course from the list of elective subjects in the syllabus.**	60	24	40	16	100	5
PE1002		60	24	40	16	100	5
PE1003		60	24	40	16	100	5
PE1004		60	24	40	16	100	5

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SYLLABUS
Integrated M.Sc. in Physics
Center for Basic Sciences
Pt. Ravishankar Shukla University, Raipur (C.G.)

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Contents

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SEMESTER- I

1.1 P101: Introductory Physics-I (For all streams)

UNIT - I

The Relation of Physics to Other Sciences: Chemistry, Biology, Astronomy, Geology, Psychology Conservation of Energy: What is energy?, Gravitational potential energy, Kinetic energy, Other forms of energy, Characteristics of Force: What is a force?, Friction, Molecular forces, Fundamental forces, Fields, Pseudo forces, Nuclear forces

UNIT - II

The Harmonic Oscillator: harmonic oscillator, Harmonic motion and circular motion, Initial conditions, Forced oscillations, Resonance: Complex numbers and harmonic motion, The forced oscillator with damping, Electrical resonance, Resonance in nature

UNIT - III

heat: Equilibrium and the zeroth law: temperature, Calibrating temperature, Absolute zero and the Kelvin scale, Heat and specific heat, Phase change, Radiation, convection, and conduction, Heat as molecular kinetic energy, Boltzmann's constant and Avogadro's number, Microscopic definition of absolute temperature

UNIT - IV

Thermodynamics: Statistical properties of matter and radiation, Thermodynamic processes, Quasi-static processes , The first law of thermodynamics, Specific heats: c_v and c_p , Cycles and state variables, Adiabatic processes, The second law of thermodynamics, The Carnot engine, Defining T using Carnot engines

UNIT - V

Entropy and Irreversibility: Entropy, The second law: law of increasing entropy, Statistical mechanics and entropy, Entropy of an ideal gas: full microscopic analysis, illustration of maximum entropy principle , Gibbs formalism, third law of thermodynamics

Suggested Texts and References:

1. **Text Book for UNIT-I and II:** "The Feynman lectures in Physics" volume 1, by R. P. Feynman, R. B. Leighton, M. Sands.

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2. **Text Book for UNIT - III, IV and V:** "Fundamentals of Physics I – Mechanics, Relativity, and Thermodynamics (Open Yale Courses)" by R. Shankar

3. **References:** "An introduction to mechanics", by D. Kleppner and R. Kolenkow.

4. "Mechanics", by Charles Kittel, Walter D. Knight and Malvin A. Ruderman, Berkeley Physics Course Volume 1.

5. "Waves", by F. S. Crawford, Berkeley Physics Course Volume 3.

6. Thermodynamics, Kinetic theory and Statistical Thermodynamics, 3rd Edition, F. W. Sears and G. L. Salinger, Narosa Publishing House, 1998.

7. Heat and Thermodynamics, 8th Edition, M. W. Zemansky and R. H. Dittman, Tata McGraw – Hill Education, 2011.

8. University Physics, 7th Edition, Francis W. Sears, Mark Zemansky and Hugh D. Young, Massachusetts: Addison Wesley, 1987.

1.2 PL101: Physics Laboratory – I

Introduction to experimental physics – conceptual and procedural understanding, planning of experiments; Plots (normal, semi-log, log-log); uncertainty / error in measurements and uncertainty / error analysis. Introduction to measuring instruments – concepts of standards and calibration; determination of time periods in simple pendulum and coupled strip oscillator system with emphasis on uncertainty in the measurements and accuracy requirements; study of projectile motion – understand the timing requirements; determination of surface tension of a liquid from the study of liquid drops formed under the surface of a glass surface; determination of Young's modulus of a strip of metal by double cantilever method (use of travelling microscope); study of combination of lenses and nodal points and correspondence to a thick lens; study of thermal expansion of metal – use of thermistor as a thermometer; measurement of small resistance of a wire using Carey- Fosterbridge and determine electrical resistivity of the wire; study of time dependence of charging and discharging of capacitor using digital multimeter – use of semi-log plot.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London

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SEMESTER - II

2.1 P201: Introductory Physics-II (For all streams)

UNIT - I

The Electric Field: Review of key ideas, Digression on nuclear forces, The electric field E, Visualizing the field, Field of a dipole, Far field of dipole: general case, Response to a field, Dipole in a uniform field, Gauss's Law: Field of an infinite line charge, Field of an infinite sheet of charge, Spherical charge distribution: Gauss's law, Digression on the area vector dA, Composition of areas, An application of the area vector, Gauss's law through pictures, Continuous charge density

UNIT - II

Application of Gauss's Law: Applications of Gauss's law, Field inside a shell, Field of an infinite charged wire, Field of an infinite plane, Conductors, Field inside a perfect conductor, The net charge on a conductor, A conductor with a hole inside, Field on the surface of a conductor

UNIT - III

Magnetism: Experiments pointing to magnetism, Examples of the Lorentz force, the cyclotron, Lorentz force on current-carrying wires, The magnetic dipole, The DC motor, Biot-Savart Law, field of a loop,Microscopic description of a bar magnet, Magnetic field of an infinite wire, Ampere's law, Maxwell's equations (static case)

UNIT - IV

Wave Theory of Light: Interference of waves, Adding waves using real numbers, Adding waves with complex numbers, Analysis of interference, Diffraction grating, Single-slit diffraction, Understanding reflection and crystal diffraction, Light incident on an oil slick, Normal incidence, Oblique incidence

UNIT - V

Optics: The Principle of Least Time Light, Reflection and refraction, Fermat's principle of least time, Applications of Fermat's principle, Geometrical Optics: The focal length of a spherical surface, The focal length of a lens, Magnification, Compound lenses, Aberrations, Resolving power, Color Vision: The human eye, dependence of Color intensity, Measuring the color sensation, The chromaticity diagram, The mechanism of color vision, Physiochemistry of color vision, Mechanisms of Seeing: The sensation of color, The physiology of the eye, The rod cells, The compound (insect) eye, Other eyes, Neurology of vision

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Suggested Texts and References:

1. **Text Book for UNIT - I to IV:** "Fundamentals of Physics II – Electromagnetism, Optics, and Quantum Mechanics: 2 (The Open Yale Courses Series)" by R. Shankar

2. **Text Book for UNIT - V:** "The Feynman lectures in Physics" volume 1, by R. P. Feynman, R. B. Leighton, M. Sands.

3. **References:** Electricity and Magnetism, Berkeley Physics Course Vol. 2, 2nd Edition, Edward M. Purcell, Tata McGraw Hill, 2011.

4. The Feynman Lectures on Physics Vol. 2, R. P. Feynman, R. B. Leighton and M. Sands, Narosa Publications, 2010.

5. Fundamentals of Optics, 4th Edition, F. A. Jenkins and H. E. White, Tata McGraw Hill, 2011.

6. University Physics, 7th Edition, Francis W. Sears, Mark Zemansky and Hugh D. Young, Massachusetts: Addison Wesley, 1987.

7. Optics , 4th Edition Eugene Hecht Massachusetts: Addison Wesley

8. "Foundations of Electromagnetic Theory 4th edition, "John R. Reitz, Fredrick Milford & RobertChrist" Massachusetts: Addison Wesley, 1993

9. Fundamentals of Optics 4th Edition Francis A. Jenkins and Harvey E. White "New York Mc Graw Hill Book Company Inc. 2001"

10. Optical Physics 3rd Edition "Stephen G. Lipson, Henry Lipson & D. S. Tannhauser" New York Cambridge University Press 1995

2.2 PL201: Physics Laboratory – II

Review of uncertainty / error analysis; least squares fit method; introduction to sensors / transducers; determination of 'g' (acceleration due to gravity) by free fall method; study of physical pendulum using a PC interfaced apparatus – study variation of effective 'g ' with change of angle of plane of oscillation - investigation of effect of large angle of oscillation on the motion; study of Newton's laws of motion using a PC interfaced apparatus; study of conservation of linear and angular momentum using Maxwell's needle' apparatus; study of vibrations of soft massive spring; study of torsional oscillatory system; study of refraction in a prism - double refraction in calcite and quartz; study of equipotential surface using different electrode shapes in a minimal conducting liquid medium; determination of electrical inductance by vector method and study effect of ferromagnetic core and study the effect of non-linearity of inductance with current.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London

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2.3 G201- Electronics & Instrumentation

UNIT - I

The Circuit Abstraction: The Power of Abstraction, The Lumped Circuit Abstraction, The Lumped Matter Discipline, Limitations of the Lumped Circuit Abstraction, Practical Two-Terminal Elements, Batteries, Linear Resistors, Associated Variables Convention, Ideal Two-Terminal Elements, Ideal Voltage Sources, Wires, and Resistors, Element Laws, The Current Source, Another Ideal Two-Terminal Element, Modeling Physical Elements, Signal Representation, Analog Signals, Digital Signals, Value Discretization

UNIT - II

Resistive Networks: Terminology, Kirchhoff's Laws, KCL, KVL, Circuit Analysis: Basic Method, Single-Resistor Circuits, Quick Intuitive Analysis of Single-Resistor Circuits, Energy Conservation, Voltage and Current Dividers, Intuitive Method of Circuit Analysis: Series and Parallel Simplification, Circuit Examples, Dependent Sources and the Control Concept Circuits with Dependent Sources, A Formulation Suitable for a Computer Solution
Network Theorems: The Node Voltage, The Node Method, Floating Independent Voltage Sources, Dependent Sources and the Node Method, The Conductance and Source Matrices, Loop Method, Superposition, Superposition Rules for Dependent Sources, Thevenin's Theorem and Norton's Theorem, The Thevenin Equivalent Network, The Norton Equivalent Network,

UNIT - III

Number Systems and Codes: Decimal Odometer, Binary Odometer, Number codes, Binary-to-Decimal conversion, Decimal-to-Binary conversion, Hexadecimal Numbers, Hexadecimal-to-Binary conversion, Binary-to-Hexadecimal conversion, Decimal-to-Hexadecimal conversion, BCD Numbers, ASCII code
Digital electronics: Review of basic logic gates; DeMorgan's theorem, Use of NAND / NOR as universal building blocks; arithmetic circuits; binary addition, half adder, full adder, binary subtraction - 1s and 2s complement, controlled inverter, adder / subtracter, parity checker

UNIT - IV

Introduction to measurements: Measurement units, Measurement system applications, Elements of a measurement system, Choosing appropriate measuring instruments
Instrument types and Performance Characteristics: Review of instrument types, Active and passive instruments, Null-type and deflection-type instruments, Analogue and digital instruments, Indicating instruments and instruments with a signal output, Smart and non-smart instruments
Static characteristics of instruments: Accuracy and inaccuracy (measurement uncertainty), Precision/ repeatability/ reproducibility, Tolerance, Range or span, Linearity, Sensitivity of measurement, Threshold, Resolution, Sensitivity to disturbance, Hysteresis effects, Dead space
Dynamic characteristics of instruments: Zero order instrument, First order instrument, Second order instrument, Necessity for calibration

UNIT - V

Errors during the Measurement Process: Sources of systematic error, System disturbance due to measurement, Errors due to environmental inputs, Wear in instrument components, Connecting leads, Reduction of systematic errors, Careful instrument design, Method of opposing inputs, High-gain

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feedback, Calibration, Manual correction of output reading, Intelligent instruments, Quantification of systematic errors, Random errors, Statistical analysis of measurements subject to random errors, Graphical data analysis techniques – frequency distributions, Aggregation of measurement system errors, Combined effect of systematic and random errors, Aggregation of errors from separate measurement system components, Total error when combining multiple measurements
Calibration of Measuring Sensors and Instruments: Principles of calibration, Control of calibration environment, Calibration chain and traceability, Calibration records

Suggested Texts and References:

1. **Text Book for UNIT - I and II:** Foundations of Analog and Digital Electronic Circuits. Agarwal, Anant, and Jeffrey H. Lang. San Mateo, CA: Morgan Kaufmann Publishers, Elsevier
2. **Text Book for UNIT - III:** "Digital Computer Electronics", Tata McGraw-Hill (Third Edition) by Albert P. Malvino, Jerald A. Brown
3. "Electronics Principals and Applications" Tata McGraw-Hill, (Ninth Edition), Charles A. Schuler
4. **Text Book for UNIT-IV and V:** "Measurements and Instrumentation Principles", Third Edition, by Alan S. Morris
5. "Electronic Devices and Circuit Theory" by R. L. Boylestad, L. Nashelsky, K. L.Kishore, Pearson
6. "Electronic Principles" by Malvino and Bates
7. "Electronic Circuit Analysis and Design" by Donald A. Neamen, Tata McGraw Hill
8. "Electronic Devices and Circuits" by David A. Bell
9. "Digital Principles and Applications" by Leach, Malvino and Saha
10. "Modern Digital Electronics", Tata McGraw-Hill (2003) by R.P. Jain
11. "Digital Design", Pearson Education Asia, (2007) by M. Morris Mano, Michael D. Ciletti
12. "Digital Fundamentals", Pearson Education Asia (1994) by Thomas L. Floyd
13. "Measurement & Instrumentation" by DVS Murthy
14. "Electrical Measurements & Electronic Measurements" by A.K. Sawhney

2.4 GL201 Electronics laboratory

1. To study the Half wave & Full wave rectifier and study the effect of C filter.
2. To design a Single Stage CE amplifier for a specific gain and bandwidth.
3. Study of Operational amplifier in inverting and non-inverting mode.
4. To verify and design AND, OR, NOT and XOR gates using NAND gates.
5. To study FLIP-FLOP circuits
6. To Study power regulator circuits

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SEMESTER - III

3.1 P301: Mathematical Physics – I

UNIT - I

Review of first order differential equations, the notion of Wronskian and its properties, Series solutions of second order differential equations, Frobenius method. Rodrigues formula and classical orthogonal polynomials, recurrence relations, symmetry properties, special values, orthogonality, normalisation.

UNIT - II

Generating functions. Legendre, Hermite, Laguerre, Bessel and Hypergeometric differential equations. Integral representations of special functions. Expansion of functions in orthonormal basis.

UNIT - III

Complex variables: Notion of analyticity, Cauchy – Riemann conditions, Harmonic functions; Contour integrals, Cauchy theorem, simply and multiply connected domains, Cauchy integral formula, derivatives of analytic functions.

UNIT - IV

Laurent series, uniform convergence; Notion of residues, residue theorem, notion of principal values, applications of residues to evaluation of improper integrals, definite integrals, indentation, branch points and branch cuts.

UNIT - V

Fourier series and simple applications. Fourier transforms, Parseval's theorem, convolution, and their simple applications. Laplace transforms, initial value problems, simple applications, transients in circuits, convolution.

Suggested Texts and References:

1. Complex Variables and Applications, R. V. Churchill and J. W. Brown, McGraw-Hill, 2009
2. Complex Variables: Introduction and Applications, 2nd Edition, M. J. Ablowitz and A. S. Fokas, Cambridge 2003
3. Differential Equations, G. F. Simmons, McGraw-Hill, 2006

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5. Mathematical Methods for Physicists, 7th Edition, G. Arfken and Hans J. Weber, Elsevier 2012.

3.2 P302: Classical Mechanics – I

UNIT - I

Recap- Newton's laws, vector algebra, gradient; momentum, energy, constraints, conservative forces, potential energy, angular momentum. Inertial and non – inertial frames, fictitious forces.

UNIT - II

Foucault pendulum, effects of Coriolis force. Central forces, conservation of energy and angular momentum, trajectories, orbits, 1/r potential (quadrature), classical scattering, two body problem, centre of mass and relative motions.

UNIT - III

Rigid body motion, moment of inertia tensor, energy and angular momentum, Euler's theorem, motion of tops, gyroscope, motion of the Earth. Introduction to Lagrangian through variational principle, applications of variational principle.

UNIT - IV

Relativity: Historical background, inconsistency of electrodynamics with Galilean relativity. Einstein's hypothesis and Lorentz transformation formula, length contraction, time dilation.

UNIT - V

Doppler shift. Energy, momentum and mass, mass – energy equivalence. Four vector notation, consistency of electrodynamics with relativity.

Suggested Texts and References:

1. An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw – Hill Education, 2007
2. Classical Mechanics, 5th Edition, T. W. B. Kibble, F. Berkshire, World Scientific 2004.
3. Introduction to Special Relativity, R. Resnik, Wiley (India), 2012
4. Spacetime Physics, 2nd Edition, E. F. Taylor, J. A. Wheeler, W. H. Freeman and Co. 1992. 5. Classical mechanics, N. C. Rana, P. S. Joag, Tata McGraw-Hill Education, 2001.

3.3 P303: Electromagnetism

UNIT - I

Electrostatics: Coulomb's law, Electric field, Gauss' law in differential and integral forms, Scalar potential, Poisson and Laplace equations, Discontinuities in Electric field and potential: electrostatic boundary conditions, Uniqueness theorem, conductors and second uniqueness theorem, method of images, multipole expansion, work and energy in electrostatics. 12

UNIT - II

Electric Fields in matter: dielectrics, polarisation, bound charges, notion of electric displacement, Gauss' law in presence of dielectrics, boundary conditions, linear dielectrics: susceptibility, permittivity, dielectric constant, boundary value problems, energy in dielectric systems.

UNIT - III

Magneto statics: Lorentz force law, steady currents, Biot – Savert law, Ampere's law, vector potential, magneto static boundary conditions, multipole expansion for vector potential, magnetic scalar potential. Diamagnets, paramagnets and ferromagnets, magnetisation, bound currents, the H field, boundary conditions, magnetic susceptibility and permeability.

UNIT - IV

Electrodynamics: Electromotive force, electromagnetic induction and Faraday's law, induced electric fields and inductance, energy in magnetic fields. Maxwell's equations: equation of continuity and Modification in Ampere's law, Gauge transformations, Lorentz and Coulomb gauge. Maxwell's equations in matter, integral and differential forms, boundary conditions.

UNIT - V

Poynting's theorem, conservation of momentum, angular momentum. Lossy media, Poynting's theorem for lossy media. Wave equation, electromagnetic waves in vacuum, plane waves, propagation in lossless and lossy linear media, absorption and dispersion, reflection at the interface of two lossy media, guided waves.

Suggested Texts and References:

1. Introduction to Electrodynamics, 4th Edition, D. J. Griffiths, Addison-Wesley 2012 2. Classical Electricity and Magnetism, 2nd Edition, W.K.H. Panofsky and M. Phillips, Dover 2005. 3. Engineering Electromagnetics, 2nd Edition, Nathan Eda, Springer 2007

3.4 P304: Waves and Oscillations

UNIT - I

Free oscillations, Simple harmonic motion, damped and forced oscillations; Coupled oscillators, normal modes, beats, infinite coupled oscillators and dispersion relation of sound; vibrating string; travelling and stationary waves; Amplitude, phase and energy. Derivation of wave equation for a string; Longitudinal and transverse waves.

UNIT - II

Waves in two and three dimensions, the wave vector, wave equation, linearity, superposition, Fourier decomposition of a wave, notion of wave packets, phase and group velocity. Example of mechanical waves (sound waves), speed of sound in air, effect of bubbles, natural observations and qualitative explanations.

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UNIT - III

String and wind instruments. Chaldni plates. Propagation in changing media, continuity conditions, characteristic impedance. Snell's laws and translation invariant boundary, prism, total internal reflection, evanescent waves. Water waves, ocean waves, Tsunami.

UNIT - IV

Electromagnetic waves, polarisation, interference.

UNIT - V

Fraunhofer diffraction. Shocks waves, boat wakes, linear analysis of the Kelvin wake. Alfven waves (qualitative).

Suggested Texts and References:

1. Waves, Berkeley Physics Course Vol. 3, Frank S. Crawford, Tata McGraw – Hill Education, 2011
2. Introduction to the Physics of Waves, Tim Freegarde, Cambridge Univ. Press 2012 3. The Physics of Waves, Howard Georgi (http://www.people.fas.harvard.edu/ hgeorgi/new.htm)

3.5 H302 : History and Philosophy of Science (All streams)

UNIT - I

History of World Science up to the Scientific Revolution: Introduction to stone age, fire, agriculture, the ceramic breakthrough, The technology of metals, discovery and development of glass, writing and scientific record, measurement-essential to all science.

urban civilization, and science. Science in Sumeria, Babylonia, and Egypt. Natural philosophy of pre-Socratic Greece.Science and technology in China and the Muslim world. Renaissance and the Copernican system. Galileo and the science of mechanics. Descartes and the mathematical method. Newton's theory of universal gravitation and optics. Growth and characteristics of the scientific revolution.

UNIT - II

History of Ancient Indian Science: Indian civilization from pre-historic times to the Indus Valley Civilization. Ancient Indian mathematics and astronomy. Ancient Indian medicine and biology. Chemistry, metallurgy and technology in general in ancient India. Strengths, weaknesses and potentialities of ancient Indian science.

UNIT - III

Introduction to Philosophy of Science: What is science?, Scientific Methodology, Falsificationism, Scientific reasoning; scientific temperament; Explanation in science; Realism and instrumentalism; Scientific change and scientific revolutions.

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UNIT - IV

Rationality, Objectivity, and Values in Science Science and Pseudo-Science, demarcation criteria, group wise study and presenation of Psedoscience examples by students

UNIT - V

Eratosthenes Experiment, Great Scientific Experiments: Group wise study and presentations by students of historically significant experiments in science.

Suggested Texts and References:

1. Stephen F. Mason, Collier Books A History of the Sciences, Macmillan Pub. Co. (1962) Collier Books, Macmillan Pub. Co. (1962)
2. D. M. Bose, S. N. Sen, B. V. Subbarayappa A Concise History of Science in India, INSA (1971)
3. Samir Okasha, Philosophy of Science – A Very Short Introduction, Oxford University Press (2002)
4. Thomas Crump, A Brief History of Science: As Seen Through the Development of Scientific Instruments, Running Press; Carroll & Graf ed. edition (2 December 2001)
5. Ron Harre Great Scientific Experiments Oxford University Press (1983)
6. Lloyd Motz and Jefferson Hane Weaver The Story of Physics, Avon Books (1992)
7. Colin A. Ronan The Cambridge illustrated History of World Science Cambridge-Newnes (1982)
8. Ed. HelaineSelin and Roddam Narasimha Encyclopaedia of Classical Indian Sciences University Press (2007)
9. The Dawn of science: Glimpses from history for the curious mind, Thanu Padmanabhan & Vasanthi Padmanabhan,Springer (2019)
10. Martin curd, & J. A. Cover, Philosophy of science: The Central Issues, W. W. Norton & Company
11. Articles from Wikipedia on History and philosophy of science
12. James Ladyman, Understanding Philosophy of science, Routledge (2002)
13. https://plato.stanford.edu/entries/pseudo-science/

3.6 PL301: Physics Laboratory – III

Frequency response of R-C circuit (concept of cut-off freq and filter) and frequency response of LC circuit; concepts of phase difference between voltage and current in these circuits, phase factor for appliances using AC mains supply; R-L-C (series / parallel) resonance; transient response in RL-C series circuit; study of Newton's rings and interference in wedge shaped films; study of double refraction in calcite / quartz prisms, polarisation of the refracted light rays, optical activity in dextrose and fructose; soldering experience – make a gated timer with indicator; measurement of heat capacity of air; Use of thermocouple / platinum resistance thermometer, use of instrumentation amplifier in amplifying signal from thermocouple; study of the laws of a gyroscope; determination of the charge of an electron by Millikan's oil drop experiment.

Suggested Texts and References:

1. Advanced Practical Physics for Students, B. L. Worsnop and H. T. Flint, Methuen and Co. Ltd., London.

3.7 GL301: Applied Electronics Laboratory

The course is based on the micro-controller system expEYES and 'Microhope' based on ATmega32 micro controller, developed at IUAC, under a UGC programme. Use of expEYES kit for monitoring pendulum motion, charge and discharge of capacitor etc to appreciate the goal of the course; Revision of concepts of binary numbers: 'Bit', 'Byte', 'Word', hexa-decimal numbers; Concepts of microprocessor and micro controllers - CPU, registers, memory (RAM, ROM, different kinds of ROM), data and address bus, decoder, encoder, instruction set, etc. Review of concepts of Digital to Analogue Conversion (DAC) and Analogue to Digital Conversion (ADC), Introduction to micro-controller ATmega32 (which is used in expEYES). Concepts of programming, flow chart, assembly language, and simulator. Concept of I/O programming for ATmega32 Examples of simple I/O program in assembly language, assemble it in an assembler in a PC and download the hex code into micro controller kit 'microhope' through USB port and verify the operation. C language for writing larger programmes, such as monitoring temperature, which uses ADC of ATmega32. Concept of interrupt and its use in real time data acquisition. Introduction to elements of PYTHON language. Concepts of how expEYES system program resident in ATmaga32 is interfaced to commands from PC in Python language; Automated measurement of simple experiments under expEYES, such as, applications such as temperature monitor, pH meter, calorimeter, protein measurement experiments, etc., will be done. As a part of these applications, introduction will be given to sensors, such as temperature sensors, pressure sensors, humidity, pH sensors, photodetectors etc, The experiments will also include I/O programme for keypad inputs and LCD display.

Suggested Texts and References:

1. Phoenix: Computer Interfaced Science Experiments, B.P. Ajith Kumar at http://www.iuac.res.in/ elab/
2. expEYES micro-controller system B.P. Ajith Kumar at http://www.iuac.res.in/ elab/phoenix/
3. The AVR micro-controller and embedded systems using assembly and C, by A.A. Mazidi, S.Naimi and S.Mnaimi, Pearson Publications, Delhi, 2013.

SEMESTER - IV

4.1 P401: Mathematical Physics – II

UNIT - I

Review of curvilinear coordinates, scale factors, Jacobian. Partial differential equations in curvilinear coordinates, classification. Laplace equation, separation of variables, boundary conditions and initial conditions, examples.

UNIT - II

Inhomogeneous equations, Green's functions in 1, 2 and 3 dimensions.

UNIT - III

Tensors calculus: contravariant and covariant notation, Levi-Civita symbol, pseudotensors, quotient rule, dual tensors.

UNIT - IV

Integral equations: Fredholm and Volterra equations, separable kernel, applications. Elementary group theory and group representations, cyclic, permutation groups; isomorphism, homomorphism.

UNIT - V

subgroups, normal subgroup, classes and cosets; orthogonal, rotation group, Lie group; equivalent, reducible, irreducible; Schur's lemma.

Suggested Texts and References:

1. Mathematical Methods for Physicists, 7th Edition, G. Arfken and Hans J. Weber, Elsevier 2012
2. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover 1996
3. Mathematics for Quantum Mechanics, 4th Edition, J. D. Jackson, Dover 2009.
4. Elements of Group Theory for Physicists, A. W. Joshi
5. Lectures on Groups and Vector Spaces for Physicists, C. J. Isham, World Scientific 1989
6. Group Theory and Its Application to Physical Problems, M. Hemmermesh, Dover 1989
7. Elements of Green's Functions and Propagation, G. Barton, Oxford 1989.

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4.2 P402: Quantum Mechanics – I

UNIT - I

Quantum Mechanics: The Main Experiment, Double-slit experiment with light, Trouble with Maxwell, Digression on photons, Photoelectric effect, Compton effect, Matter waves, Photons versus electrons, The Heisenberg uncertainty principle, states of position and momentum in QM, Heisenberg microscope, The wave function Ψ, Collapse of the wave function

UNIT - II

The Wave Function and Its Interpretation, Probability in classical and quantum mechanics, Statistical concepts: mean and uncertainty, Quantization and Measurement, More on momentum states, Single-valuedness and quantization of momentum, Quantization, The integral of $\Psi_p(x)$, Measurement postulate: momentum An example solvable by inspection, Using a normalized Ψ, Finding $A(p)$ by computation, Fourier's theorems

UNIT - III

Measurement postulate: general, More than one variable, States of Definite Energy, Free particle on a ring, Analysis of energy levels: degeneracy, Particle in a well, The box: an exact solution, Energy measurement in the box

UNIT - IV

Scattering and Dynamics, Quantum scattering (1-D), Scattering for $E > V_0$ Scattering for $E < V_0$, Tunneling, Quantum dynamics, A solution of the time dependent Schrödinger equation, Derivation of the particular solution $\Psi_E(x,t)$, Special properties of the product solution, General solution for time evolution, Time evolution: a more complicated example

UNIT - V

Discussion on postulates of quantum mechanics, Eigenvalue problem, The Dirac delta function and the operator X, Postulates: final. Many particles, bosons, and fermions, Identical versus indistinguishable, Implications for atomic structure, Energy-time, uncertainty principle
Time-Independent Schrödinger Equation: Stationary States, The Infinite Square Well, The Harmonic Oscillator, Algebraic Method, Analytic Method, The Free Particle, The Delta-Function Potential, Bound States and Scattering States, The Delta-Function Well, The Finite Square Well

Suggested Texts and References:

1. **Text Book for UNIT I to IV :** "Fundamentals of Physics II – Electromagnetism, Optics, and Quantum Mechanics: 2 (The Open Yale Courses Series)" by R. Shankar

2. **Text Book for UNIT V :** "Introduction to Quantum Mechanics", 2nd Edition, D. J. Griffiths, Pearson Education 2008.

3. **References:** Quantum Mechanics, 3rd Edition, L. I. Schiff, Tata McGraw-Hill 2010.

4. Quantum Mechanics I and II, Claud Cohen Tannoudji, B. Diu and F. Laloe, Wiley 2006

5. Lectures on Quantum Mechanics, S. Weinberg, Oxford University Press 2012.

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4.3 PCB 401: Physical and Chemical Kinetics

UNIT - I

Basic Concepts: Rate, order and molecularity of a reaction, Specific rate and specific rate constant, First, second and third order reactions – effect of concentration on reaction rate, rate expressions and integrated form, pseudo-unimolecular, nth order reaction of a single component.

UNIT - II

Kinetic Measurements:Experimental determination of reaction rates and order of reactions, Integrated rate method, Vant Haff differential rate method, Graphical method, Half life method, Ostwald dilution law method, initial rate as a function of initial concentrations. Order of complex reaction, Steady State approximation method, Equilibrium method, relaxation methods for fast reaction

UNIT - III

Factors Affecting Reaction Rate: Effect of temperature on reaction rate – Arrhenius equation and activation energy, temperature coefficient theory, overall rate constant, overall activation energy, overall pre-exponential factor, effect of ionic strength on reactions between ions, kinetic salt effect, effect of solvent on ionic reaction, dielectric constant, linear free energy relationship

UNIT - IV

Complex Reactions: Kinetics of parallel first order reaction, Wegscheider Test, kinetics of reversible reaction/opposing reaction, kinetics of consecutive reaction, kinetics of photochemical reaction, radioactive decay, complex mechanisms involving equilibria.

UNIT - V

Catalysis:Homogeneous catalysis, basis of catalytic action, catalysis and the equilibrium constant, Michaelis-Menten kinetics, acid base catalysis, the Bronsted catalysis law,negative catalysis and inhibition,heterogeneous catalysis, surface reactions – effect of temperature and nature of surface

Suggested Texts and References:

1. K.A. Connors, Chemical Kinetics : A Study of Reaction Rates in Solution, V.C.H. Publications 1990.

2. J.I. Steinfeld, J.S. Francisco and W.L. Hase, Chemical Kinetics and Dynamics, Prentice Hall 1989. (iii) Paul L. Houston, Chemical Kinetics and reaction dynamics.

3. K.J.Laidler, Chemical Kinetics, 3rd ed. Harper and Row, 1987.

4. J.W. Moore and R.G. Pearson, Kinetics and Mechanisms, John Wiley and Sons, 1981

5. A. A. Forst and R. G. Pearson, Kinetics and Mechanism, Wiley International Edition.

6. Sanjay K. Upadhay, Chemical kinetics and Reaction Dynamics, Springer, 2006

7. Puri, Sharma, Pathania, Principles of Physical Chemistry

4.4 G401: Statistical Techniques and Applications

UNIT - I

Purpose of Statistics, Events and Probabilities, Assignments of probabilities to events, Random events and variables, Probability Axioms and Theorems. Probability distributions and properties: Discrete, Continuous and Empirical distributions. Expected values: Mean, Variance, Skewness, Kurtosis, Moments and Characteristics Functions.

UNIT - II

Types of probability distributions: Binomial, Poisson, Normal, Gamma, Exponential, Chisquared, Log-Normal, Student's t, F distributions, Central Limit Theorem.

UNIT - III

Monte Carlo techniques: Methods of generating statistical distributions: Pseudorandom numbers from computers and from probability distributions, Applications. Parameter inference: Given prior discrete hypotheses and continuous parameters, Maximum likelihood method for parameter inference. Error Analysis: Statistical and Systematic Errors, Reporting and using uncertainties. Propagation of errors, Statistical analysis of random uncertainties, Averaging Correlated/ Uncorrelated Measurements.

UNIT - IV

Deconvolution methods, Deconvolution of histograms, binning-free methods. Least-squares fitting: Linear, Polynomial, arbitrary functions: with descriptions of specific methods; Fitting composite curves. Hypothesis tests: Single and composite hypothesis, Goodness of fit tests.

UNIT - V

P-values, Chi-squared test, Likelihood Ratio, Kolmogorov- Smirnov test, Confidence Interval. Covariance and Correlation, Analysis of Variance and Covariance. Illustration of statistical techniques through hands-on use of computer programs.

Suggested Texts and References:

1. Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, R.J. Barlow, John Wiley 1989.

2. The Statistical Analysis of Experimental Data, John Mandel, Dover Publications 1984.

3. Data Reduction and Error Analysis for the Physical Sciences, 3rd Edition, Philip Bevington and Keith Robinson, McGraw Hill 2003.

4.5 PL401: Physics Laboratory – IV

Application of PHOENIX (IUAC, New Delhi) microcontroller system for automation in 20 experiments (six sessions); study of acoustic resonance in Helmholtz resonator using PHOENIX system; Resolving power of optical grating; study of atomic spectra in hydrogen, helium, mercury; Application of gamma counts from detected by G.M. counter for study of Poisson and Gaussian distributions;

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study of black body radiation by optical and thermal radiations; study of electrically coupled oscillators – normal and transient response. Assembling components for an experiment on thermal and electrical conductivity of metals and making of measurements.

Suggested Texts and References:

1. Phoenix: Computer Interfaced Science Experiments – http://www.iuac.res.in/ elab/phoenix/
2. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991.
3. Manual of Experimental Physics with Indian Academy of Sciences, Bangalore kit, R. Srinivasan and K.R.S. Priolkar.

4.6 GL401: Computational Laboratory and Numerical Methods

1. GNU Plot, FORTRAN90, Pointers and Object Oriented Programming
2. The nature of computational physics: Machine representation, precision and errors in computation. Errors and uncertainties. E.g. One should understand how to analyze whether a calculation is limited by the algorithm or round-off error. Single/double precision.
3. Basic tools for numerical analysis in science: Solution of algebraic functions – Fixed point method, Newton-Raphson method, Secant method. Numerical Integration – Rectangular method, trapezoidal method. Lagrange's interpolation.
4. Matrix Algebra: Approximate solution of a set of linear simultaneous equations by GaussSidel iteration method. Exact solution by Gaussian elimination. Inversion of a matrix by Gaussian elimination. Determining all the eigenvalues of a real symmetric matrix by Householder's method of tridiagonalization followed by QR factorization of the tridiagonalized matrix.
5. Differential Equations (ODE and PDE): Solution of an ODE by Euler's method and RungeKutta (4) method – comparison of convergence Solution of partial differential equation (Laplace's equation and Poisson's equation) – Boundary Value Problem – solved using Gauss-Sidel iteration followed by plotting using GNUPlot .
6. Nonlinear Systems, dynamics: Fractals – generating the Mandelbrot set and Julia sets. Definition of each. Solution of nonlinear set of ODEs – Lorenz equations – Observation and definition of strange attractor and sensitive dependence upon initial conditions (butterfly effect). Study of the logistic map – non linear dynamical system – obtaining a bifurcation diagram and estimating Feigenbaum's constant.
7. Fourier analysis of nonlinear systems: Getting used to programming using FFT subroutines. Understanding the relationship between time-domain and frequency domain. Transforming a Gaussian, understanding how temporal FWHM and spectral FWHM are related. Solving a nonlinear PDE which is amenable to solution by multiple steps of FFTs.

SEMESTER - V

5.1 P501: Quantum Mechanics – II

UNIT - I

Formalism of quantum mechanics: Hilbert Space, Observables, Hermitian Operators, Determinate States, Eigenfunctions of a Hermitian Operator, Discrete Spectra, Continuous Spectra, Generalized Statistical Interpretation, The Uncertainty Principle, Proof of the Generalized Uncertainty Principle, The Minimum-Uncertainty Wave Packet, The Energy-Time Uncertainty Principle, Vectors and Operators, Bases in Hilbert Space, Dirac Notation, Changing Bases in Dirac Notation
Quantum Mechanics in Three Dimensions: The Schröger Equation, Spherical Coordinates, The Angular Equation, The Radial Equation, The Hydrogen Atom, The Radial Wave Function, The Spectrum of Hydrogen, Angular Momentum, Eigenvalues, Eigenfunctions, Spin, Spin 1/2, Electron in a Magnetic Field, Addition of Angular Momenta, Electromagnetic Interactions, Minimal Coupling, The Aharonov–Bohm Effect

UNIT - II

Identical Particles: Two-Particle Systems, Bosons and Fermions, Exchange Forces, Spin, Generalized Symmetrization Principle, Atoms, Helium, The Periodic Table, Solids, The Free Electron Gas, Band Structure

UNIT - III

Time-Independent Perturbation Theory: Nondegenerate Perturbation Theory, General Formulation, First-Order Theory, Second-Order Energies, Degenerate Perturbation Theory, Two-Fold Degeneracy, "Good" States, Higher-Order Degeneracy, The Fine Structure of Hydrogen, The Relativistic Correction, Spin-Orbit Coupling, The Zeeman Effect, Weak-Field Zeeman Effect, Strong-Field Zeeman Effect, Intermediate-Field Zeeman Effect, Hyperfine Splitting in Hydrogen.

UNIT - IV

The Variational Principle: Theory, The Ground State of Helium, The Hydrogen Molecule Ion, The Hydrogen Molecule
The WKB Approximation, The "Classical" Region, Tunneling, The Connection Formulas

UNIT - V

Scattering: Classical Scattering Theory, Quantum Scattering Theory, Partial Wave Analysis, Formalism, Strategy, Phase Shifts, The Born Approximation, Integral Form of the Schrödinger Equation,

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The First Born Approximation, The Born Series

Suggested Texts and References:

1. **Text Book for UNIT I to V:** Introduction to Quantum Mechanics, 2nd Editon, D. J. Griffiths, Pearson Education 2008.
2. **References** Quantum Mechanics, 3rd Edition, L. I. Schiff, Tata McGraw-Hill 2010.
3. Quantum Mechanics I and II, Claud Cohen Tannoudji, B. Diu and F. Laloe, Wiley 2006
4. Lectures on Quantum Mechanics, S. Weinberg, Oxford University Press 2012.
5. Quantum Mechanics: Theory and Applications, A. ghatak, S. Loknathan.
6. Quantum Mechanics Concepts and Applications, Nouredine Zettili, second edition

5.2 P502: Classical mechanics – II

UNIT - I

Variational principle (revisited), Lagrangian formulation, constraints, generalised coordinates, applications. Hamilton's equations of motion (from Legendre transformation), Hamiltonian and total energy, cyclic coordinates, variational principle.

UNIT - II

Small oscillations, single oscillator, damped and forced oscillations, coupled oscillators, normal modes.

UNIT - III

Canonical transformations, Poisson brackets, conservation theorems.

UNIT - IV

Hamilton – Jacobi theory, action – angle variables. Canonical perturbation theory, time dependent and time independent.

UNIT - V

Lagrangian formulation of continuous media as a limiting case, extensions.

Suggested Texts and References:

1. Classical mechanics, N. C. Rana, P. S. Joag, Tata McGraw-Hill Education, 2001.
2. Mechanics, L. D. Landau, E. M. Lifshitz, Elesevier 2005.
3. Regular and Chaotic Dynamics, 2nd Edition, A. J. Lichtenberg, M. A. Lieberman, Springer 1992.
4. Classical mechanics, 3rd Edition, H. Goldstein, C. P. Poole, J. Safko, Pearson Education 2011.

5.3 P503: Atomic and Molecular Physics

UNIT - I

Many – electron atoms: One – electron wavefunctions and energies in Coulomb potential (revision); Atomic orbitals, spin – orbit coupling, Thomas precession, fine structure; Alkali atoms; Helium ground state and excited states, direct and exchange integrals; Many – electron atoms: LS and jj coupling schemes; Hartree – Fock method; Pauli's principle and the Periodic Table; Nuclear spin and hyperfine structure.

UNIT - II

Atoms in External Fields: Quantum theory of normal and anomalous Zeeman effect, Linear and quadratic Start effect; Semi – classical theory of radiation; Absorption and induced emission; Einstein's A and B coefficients, dipole approximation, intensity of radiation, selection rules.

UNIT - III

Two level atom in a coherent radiation field, Rabi frequency, radiative damping, optical Bloch equation, Broadening of spectral lines (Doppler, pressure and power broadening).

UNIT - IV

Lasers: Basic concepts, rate equation and lasing conditions, working of some common lasers. Doppler free laser spectroscopy; Crossed – beam method, saturated absorption spectroscopy, two photon spectroscopy; Laser cooling and trapping (descriptive); Atom interferometry (descriptive).

UNIT - V

Molecules: Ionic and covalent bonding, Hydrogen molecular ion (H2 +), Born – Oppenheimer approximation; Bonding and anti – bonding orbitals, Hydrogen molecule; Heitler – London method, Molecular orbital method, hybridisation, quantum mechanical treatment of rotational and vibrational spectra (diatomic and polyatomic molecules); Electronic spectra, Raman effect (classical and quantum theory); Vibrational and rotational Raman spectra; Electron spin resonance.

Suggested Texts and References:

1. Atomic Physics, Christopher Foot, Oxford University Press, 2005.
2. Intermediate Quantum Mechanics, 3rd Edition, H. A. Bethe and R. W. Jackiew, Persius 1997
3. The Physics of Atoms and Quanta: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2005
4. Molecular Physics and Elements of Quantum Chemistry: Introduction to Experiments and Theory, H. Haken, H. C. Wolf and W. D. Brewer, Springer 2010.

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5.4 PM501: Numerical Analysis

UNIT - I

Error, its sources, propagation and analysis; Errors in summation, stability in numerical analysis. Linear algebraic equations: Gaussian elimination, direct triangular decomposition, matrix inversion.

UNIT - II

Root finding: review of bisection method, Newton's method and secant method; real roots of polynomials, Laguerre's method. Matrix eigenvalue problems: Power method, eigenvalues of real symmetric matrices using Jacobi method, applications.

UNIT - III

Interpolation theory: Polynomial interpolation, Newton's divided differences, forward differences, interpolation errors, cubic splines. Approximation of functions: Taylor's theorem, remainder term; Least squares approximation problem, Orthogonal polynomials.

UNIT - IV

Numerical integration: review of trapezoidal and Simpson's rules, Gaussian quadrature; Error estimation. Numerical differentiation. Monte Carlo methods.

UNIT - V

Least squares problems: Linear least squares, examples; Non – linear least squares. Ordinary differential equations: stability, predictor – corrector method, Runge – Kutta methods, boundary value problems, basis expansion methods, applications. Eigenvalue problems for differential equations, applications. Solutions of PDE's using differential quadrature: elementary treatment. Applications to diffusion equation, wave equation, etc.

Suggested Texts and References:

1. An introduction to Numerical Analysis, 2nd Edition, Kendall Atkinson, Wiley 2012
2. Numerical Methods for Scientists and Engineers, H. M. Antia, Hindustan Book Agency 2012.
3. Numerical Receipes in Fortran, 2nd Edition, W. H. Press et al., Cambridge University Press 2000.

5.5 PL501: Physics Laboratory - V

Study of diffraction by single slit, double slit and multiple slits leading to grating, quantitative determination and compare with simulation; Study of Michelson interferometer and determination of refractive index of air; study of Fabry-Perot interferometer; Study of Zeeman effect using Fabry-Perot Interferometer; study of characteristics of scintillation counter used in nuclear radiation detection; study of Hall effect in semiconductors; Introduction to Labview software for automation and use of NI data acquisition card in PC (six sessions).

Suggested Texts and References:

1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991

5.6 PML501: Numerical Methods Laboratory

The methods developed in Numerical Analysis (P501) are to be implemented on a computer. Emphasis to be given on applications to physical problems.

Suggested Texts and References:

1. Numerical Receipes in Fortran, 2nd Edition, W. H. Press et al., Cambridge University Press 2000

2. An Introduction to Computational Physics, 2nd Edition, Tao Pang, Cambridge University Press 2010

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SEMESTER - VI

6.1 P601: Electrodynamics

UNIT - I

Review of Maxwell's equations, vector and scalar potentials, gauge transformations. Radiating systems: electric dipole fields and radiation, magnetic dipole and electric quadrupole fields, antenna, spherical wave solutions of the scalar wave equation.

UNIT - II

Multipole expansion of the electromagnetic fields, energy and angular momenta of multipole radiation, angular distribution of multipole radiation, multipole moments, multipole radiation in atoms and nuclei, multipole radiation from linear centre fed antenna.

UNIT - III

Scattering and Diffraction problems: scattering at long wavelength, perturbation theory of scattering, explanation of blue sky (due to Rayleigh), scalar diffraction theory.

UNIT - IV

Covariant formulation of electrodynamics: four vector potential, electromagnetic field tensor, covariant description of sources in material media, field equations in a material medium. Retarded potentials, Jefimenko's generalisations of Coulomb and Biot – Savert laws, Lienard – Wiechert potentials.

UNIT - V

Fields of a moving charge. Cerenkov radiation. Covariant formulation of the conservation laws of electrodynamics.

Suggested Texts and References:

1. Introduction to Electrodynamics, 4th Edition, D. J. Griffiths, Addison-Wesley 2012
2. Classical Electricity and Magnetism, 2nd Edition, W.K.H. Panofsky and M. Phillips, Dover 2005
3. Classical Electrodynamics, 3rd Edition, J. D. Jackson, Wiley 2012
4. Lectures on Electromagnetism, 2nd Edition, Ashok Das, Hindustan Book Agency 2013.

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6.2 P602: Statistical Mechanics - I

UNIT - I

Elementary probability theory; random walk; binomial, Poisson, log normal distributions; the Gaussian. Kinetic theory of gases.

UNIT - II

Ensembles; micro-canonical ensemble; canonical ensemble; grand canonical ensemble. Partition functions and their properties; calculation of thermodynamic quantities; Gibbs paradox; the equipartition theorem.

UNIT - III

Two level system and paramagnetism. Validity of the classical approximation; identical particles and symmetry; quantum distribution functions; Bose-Einstein statistics; Fermi-Dirac statistics;

UNIT - IV

Quantum Statistics in the classical limit; physical implications of the quantum-mechanical enumeration of states; conduction electrons in metals.

UNIT - V

Special topics: the Chandrasekhar Limit; Saha Ionization formula. Systems of interacting particles; Debye approximation; van der Waals equation; Weiss molecular-field approximation.

Suggested Texts and References:

1. Thermodynamics and an Introduction to Thermostatistics, 2nd Edition, H. B. Callen, Wiley 2006
2. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill Book Company
3. Statistical Physics part 1, 3rd Edition, L. D. Landau and E. M. Lifshitz, Elsevier 2008
4. Statistical Mechanics: A Set of Lectures, R. P. Feynman, W. A. Benjamin, Inc. 1998
5. A Modern Course in Statistical Physics, L. E. Reichl, Wiley 2009

6.3 P602 Computational Physics - A (only for SEMESTER-IV students of session 2021-22)

UNIT - I

Introduction of Fortran programming Language, Random Number generation and testing, Generation of random numbers with given distribution

16/01/2023

UNIT - II

Numerical Integration: (a) Deterministic: Trapezoidal method and (b) Multi-dimensional Integration using stochastic methods.

UNIT - III

Lattice Monte Carlo simulations using Ising model to understand phase transitions: Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations, Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations; Principle of detailed balance, calculating thermodynamic averages

UNIT - IV

Determining transition temperature using Binders cumulant, Solving differential equations, Linear, non-linear and coupled differential equations

UNIT - V

Solving differential equations Schrodinger equation. in Quantum Mechanics with Numerov's algorithm and variational principle., Classical Molecular Dynamics simulations using Lennard-Jones' potential

Suggested Texts and References:

1. Computational Physics: Problem Solving with Python, 3rd edition, Rubin H. Landau, Manuel J. Paez, Cristian C. Bordeianu
2. Computational Physics, Fortran Version, Steven E. Koonin, Dawn C.Meredith, CRC Press
3. Computational Physics,2nd edition, Jos Thijssen, Cambridge Univ. Press
4. Computational Physics, T. Pang
5. Computational Physics (An Introduction to Monte Carlo Simulations of Matrix Field Theory), Ydri, Badis
6. Computer Programing in F90 & 95, V. Rajaraman, PHI learning pvt. Ltd
7. Numerical Recipes in F90 Cambridge Publishers
8. Computational Physics by Jos Thijssen (Cambridge UnivPress, 1997)
9. A first course in Computational Physics, P. L. DeVries and J. Hasbun, John Wiley and Sons. Inc.
10. Understanding Molecular Simulation, Publisher: Academic Press, Author: Daan Frenkel and Berend Smit.

6.4 P603: Condensed Matter Physics – I

UNIT - I

Crystal Structure and x-ray diffraction: Crystalline and amorphous solids, translational symmetry. Elementary ideas about crystal structure, lattice and bases,

16/6/2023

UNIT

cell, reciprocal lattice, fundamental types of lattices, Miller indices, lattice planes, simple cubic, f.c.c. and b.c.c. lattices. Simple crystal structures, Closed packed structure, Determination of crystal structure with X-rays, Neutrons and Electron diffraction-Diffraction of waves by crystals, Laue and Bragg equations, Brillouin Zones, Fourier Analysis of the basis. Debye waller factor, X ray broadening -size and temperature effects. X-ray diffraction of liquids and disordered solids- introduction to radial distribution functions.

UNIT - II

Lattice Vibrations: Elastic waves, Thermal properties: Einstein's and Debye's theories of specific heats of solids, Thermal conductivity, Phonons, Lattice waves, Dynamics of a chain of similar atoms and chain of two types of atoms; optical and acoustic modes; Inelastic scattering of x-rays, neutrons and light by phonons, Optical properties of solids: interaction of light with ionic crystals. Raman scattering and Brillouin scattering.

UNIT - III

The Free electron model: Drude Model, Electron conductivity, Heat capacity of conduction electrons, Fermi surface, Sommerfield model, Thermal conductivity of metals, Hall effect, AC conductivity and optical properties, Wiedemann-Franz law, Failure of the Free-electron model, optical properties of metals.

UNIT - IV

Basics of Semiconductors and device: Crystal structure, Band structure, Intrinsic and extrinsic semiconductors, Concept of majority and minority carriers, Energy gap, Mobility, conductivity, Hall effect, Diffusion, Optical properties: Absorption, Luminescence, Photoconductivity, effect of disorder on absorption. Interpretation of energy band diagrams. Devices: p-n diode (derivation of Shockley equation), tunnel diode, photodiode, solar cell, LED, Lasers.

UNIT - V

Superconductivity: Introduction (Kamerlingh Onnes experiment), effect of magnetic field, Type- I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Electrodynamics of superconductivity: London's equation, Thermodynamics of the transition, Intermediate state of Type 1, Mixed state of type 2, Flux Quantization, Salient points of BCS theory, Cooper problem, Definition of coherence length, Josephson effect.

Suggested Texts and References:

1. Elementary Solid State Physics, M. Ali Omar, Pearson Education 2008.
2. Introduction to Solid State Physics, 8th Edition, C. Kittel, Wiley 2012.
3. Solid State Physics, N. W. Ashcroft and N. D. Mermin, Cengage 2003.
4. Physics of Semiconductor Devices, 3rd Edition, S. M. Sze and K. K. Ng, 2007.
5. Introduction to Superconductivity, A. C. Rose -Innes, E. H. Rhoderik, Pergamon Press

6. Solid State Physics, J. P. McKelvey, Krieger Publishing Co. 1993.

7. Electron theory of solids, J. M. Ziman, Cambridge University Press, 2011.

6.5 P604: Lasers

UNIT - I

Laser Characteristics –Spontaneous and stimulated emission, Einstein's quantum theory of radiation, theory of some optical processes, coherence and monochromacity, kinetics of optical absorption, line broadening mechanism, Basic principle of lasers, population inversion, laser pumping, two & three level laser systems, resonator, Q-factor, losses in cavity, threshold condition, quantum yield.

UNIT – II

Laser Systems- Solid state lasers- the ruby laser, Nd:YAG laser, ND: Glass laser, semiconductor lasers – features of semiconductor lasers, intrinsic semiconductor lasers, Gas laser -neutral atom gas laser, He-Ne laser, molecular gas lasers, CO2 laser, Liquid lasers, dye lasers and chemical laser.

UNIT - III

Advances in laser Physics, Production of giant pulse -Q-switching, giant pulse dynamics, laser amplifiers, mode locking and pulling, Non-linear optics, Harmonic generation, second harmonic generation, Phase matching, third harmonic generation, optical mixing, parametric generation and self-focusing of light.

UNIT – IV

Multi-photon processes; multi-quantum photoelectric effect, Theory of two-photon process, three-photon process, second harmonic generation, parametric generation of light, Laser spectroscopy : Rayleigh and Raman scattering, Stimulated Raman effect, Hyper-Raman effect, Coherent anti-stokes Raman Scattering, Photo-acoustic Raman spectroscopy.

UNIT – V

Laser Applications – ether drift and absolute rotation of the Earth, isotope separation, plasma, thermonuclear fusion, laser applications in chemistry, biology, astronomy, engineering and medicine. Communication by lasers: ranging, fiber Optics Communication, Optical fiber, numerical aperture, propagation of light in a medium with variable index, pulse dispersion.

Suggested Texts and References:

1. Laud, B.B.: Lasers and nonlinear optics, (New Age Int.Pub.1996).

2. Thyagarajan, K and Ghatak, A.K.: Lasers theory and applications (Plenum press, 1981).

3. Ghatak, A.K.and Thyagarajan, K : Optical electronics (Cambridge Univ. Press 1999).

4. Seigman, A.E.: Lasers (Oxford Univ. Press 1986)

5. Hecht, J.The laser Guide book (McGraw Hill, NY, 1986).

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6.6 H 601 Ethics of Science and IPR

UNIT - I

Introduction to Ethics– causes of unethical acts, Definition – moral, values, ethics; Role and importance of ethics in science; Professional ethics – professional conduct, Teaching ethical values to scientists, good laboratory practices, good manufacturing practices, Basic Approaches to Ethics; Posthumanism and Anti-Posthumanism.

UNIT - II

Medical Ethics: Different themes pertaining to medical ethics including ethical issues in public health. Environmental Ethics, Bioethics, Journals and Publishers: Monopolistic practices by Academic Publishers. Plagiarism, softwares for plagiarism detection.

UNIT- III

Introduction to IPR; Types of Intellectual property – Patents, Trademarks, Copyrights and related rights; Traditional vs. Novelty; Importance of intellectual property rights in the modern global economic environment, Importance of intellectual property rights in India.

UNIT - IV

Patents: Definition, patentable and non patentable inventions; types of patent application – Ordinary, Conventional, PCT, Divisional, and Patent of addition; Concept of Prior Art; Precautions while patenting disclosure / nondisclosure;

UNIT - V

Case studies and agreements - Evolution of GATT and WTO and IPR provisions under TRIPS; Madrid agreement; Hague agreement; WIPO treaties; Budapest treaty; Indian Patent Act (1970)

Suggested Texts and References:

1. David B. Resnik The Ethics of Science: An Introduction', Routledge, New York, 1998
2. V. K. Ahuja Intellectual Property Rights in India', 2015
3. V. K. Ahuja Law Relating to Intellectual Property Rights', 2017.

6.7 PL601: Physics Laboratory – VI

Study of quantum mechanics through acoustic analogue (four sessions); Fourier analysis / synthesis – use of simulation; Study of characteristics of a coaxial cable and determination of speed of electromagnetic waves in the coaxial cable; determination of specific charge (e/m) of electron; Study of Faraday rotation and determination of Verdit's constant in a glass material; investigation of chaos in a spring based coupled oscillator system; Introduction to workshop practice (two sessions); Introduction to vacuum practice (two sessions).

Suggested Texts and References:

1. The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991

SEMESTER - VII

7.1 P701- Astronomy and Astrophysics - I

UNIT - I

An understandable universe, The scale of the universe, Continuous radiation from stars, Brightness of starlight, The electromagnetic spectrum, Colors of stars, Quantifying color, Blackbodies, Planck's law and photons, Stellar colors, Stellar distances, Absolute magnitudes

UNIT - II

Spectral lines in stars, Spectral lines, Spectral types, The origin of spectral lines, The Bohr atom, Quantum mechanics, Formation of spectral lines, Excitation, Ionization, Intensities of spectral lines The Hertzprung–Russell diagram

UNIT - III

Telescopes, What a telescope does, Light gathering, Angular resolution, Image formation in a camera, Refracting telescopes, Reflecting telescopes, Observatories, Ground-based observing, Observations from space, Data handling, Detection, Spectroscopy, Observing in the ultraviolet, Observing in the infrared, Radio astronomy, High energy astronomy

UNIT - IV

The Sun: a typical star, Basic structure, Elements of radiation transport theory, The photosphere Appearance of the photosphere, Temperature distribution, Doppler broadening of spectral lines The chromosphere, The corona, Parts of the corona, Temperature of the corona, Solar activity Sunspots, Other activity

UNIT - V

Place, time, and motion: Astronomical coordinate systems, The third dimension, Time, Motion Names, catalogs, and databases: Star names, Names and catalogs of non-stellar objects outside the Solar System, Objects at non-optical wavelengths, Atlases and finding charts, Websites and other computer resources, Solar System objects

Suggested Texts and References:

1. **Text book for UNIT I to IV :** "Astronomy: A Physical Perspective" by Marc L. Kutner

2. **Text book UNIT V :** "To Measure the Sky: An Introduction to Observational Astronomy" by Frederick R. Chromey
3. References: Introduction to Modern Astrophysics by B. W. Carroll and D. A. Ostlie
4. An invitation to Astrophysics by T. Padmanabhan
5. Astrophysical Concepts by Martin Harwit
6. Introductory Astronomy and Astrophysics by Zelike and Gregory
7. Physical Universe by F. Shu

7.2 P702: Quantum Mechanics – III

UNIT - I

Foundations (Introductory ideas): The EPR paradox, quantum entanglement; Bell's theorem, the No-clone theorem, Schrodinger's cat; Decoherence, quantum Zeno paradox.

UNIT - II

Symmetry and Conservation Laws: Transformation of the Wave Function under Coordinate Transformations, Group of Symmetry of the Schrödinger Equation and the Conservation Laws, Homogeneity of Time and Space: Conservation of Energy and Momentum, Isotropy of Space: Conservation of Angular Momentum, Symmetry of the Hamiltonian and Degeneracy, Space Inversion Symmetry, Time Reversal Symmetry and Time Reversal Operator Kramers' Degeneracy and Kramers' Theorem

UNIT - III

Relativistic Wave Equations: Generalization of the Schrödinger Equation, the Klein-Gordon equation, Plane Wave Solutions, Charge and Current Densities, Interaction with Electromagnetic Fields, Hydrogen-Like Atom, Nonrelativistic Limit

UNIT - IV

The Dirac equation, Dirac's Relativistic Hamiltonian, Position Probability Density, Expectation Values, Dirac Matrices Plane Wave Solutions of the Dirac Equation; Energy Spectrum The Spin of the Dirac Particle, Significance of Negative Energy States; Dirac Particle in Electromagnetic Fields,

UNIT - V

Relativistic Electron in a Central Potential: Total Angular Momentum, Radial Wave Equations in Coulomb Potential, Series Solutions of the Radial Equations: Asymptotic Behaviour, Determination of the Energy Levels, Exact Radial Wave Functions, Comparison to Non-Relativistic Case, Electron in a Magnetic Field—Spin Magnetic Moment, The Spin Orbit Energy

Suggested Texts and References:

1. **Text Book for UNIT I :** Introduction to Quantum Mechanics, 2nd Editon, D. J. Griffiths, Pearson Education 2008.

2. **Text Book for UNIT-II :** Fundamentals of Quantum Mechanics, Ajit Kumar, Cambridge university press

3. **Text Book for UNIT - III to V** A Textbook of Quantum Mechanics, Second Edition, P. M. Mathews and K. Venkatesan

4. Relativistic Quantum Mechanics vol. 1: J. D. Bjorken and S. D. Drell, McGraw-Hill 1998

5. Intermediate Quantum Mechanics, H. A. Bethe and R. W. Jackiew, Perseus Books 1997

6. Quantum Field Theory, 2nd Edition, F. Mandl and G. Shaw, Wiley 2010

7. Advanced Quantum Mechanics, F. Schwabl, Springer 2008

7.3 P703: Statistical Mechanics – II

UNIT - I

Transport theory using the relaxation time approximation; Boltzmann differential equation formulation; examples of the Boltzmann equation method. Stochastic Processes; Random Walk; Autocatalytic processes.

UNIT - II

Diffusion equation; Langevin equation; Fokker- Planck equation.

UNIT - III

Ising Model; mean-field theory; Landau theory of second order phase transition; Peierls argument; the Bethe-Peierls approximation; Kramers-Wannier duality argument; Pade Approximant.

UNIT - IV

Phase transition and Critical Phenomenon: critical exponents; exponent inequalities; static scaling hypothesis; block spins and the Kadanoff construction.

UNIT - V

Renormalization Group: Decimation; Migdal-Kadanoff method; general renormalization group prescription; examples. Monte-Carlo Methods in statistical mechanics; Metropolis algorithm; Gilespie method.

Suggested Texts and References:

1. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill Book Company

2. Statistical Physics part 1, 3rd Edition, L. D. Landau and E. M. Lifshitz, Elsevier 2008

3. Statistical Mechanics: A Set of Lectures, R. P. Feynman, W. A. Benjamin, Inc. 1998

4. A Modern Course in Statistical Physics, L. E. Reichl, Wiley 2009

7.4 P704: Nuclear Physics-I

UNIT - I

Nuclear Properties: Size – nuclear radius, charge distribution, matter distribution. Mass- binding energy, liquid drop model/mass formula. Spin, Parity, isospin. Electromagnetic moments- magnetic dipole and electric quadrupole moments/nuclear shapes.

UNIT - II

Nuclear stability, alpha, beta, gamma decays, fission. Experimental methods for size, mass, spin, moments to be included.

UNIT - III

Nuclear Forces: Nuclear interaction, saturation of nuclear density, constancy of binding energy per nucleon. Bound two nucleon system, Deuteron problem, absence of bound pp, nn. N-N scattering – as a function of energy, phase shift, cross section. Salient features of nuclear force. Yukawa's theory of nuclear interaction (basics).

UNIT - IV

Nuclear Structure: Magic numbers, shell model, spin orbit interaction, deformed shell model. Nuclear excited states vibration, rotation, Collective model. Electromagnetic interactions in nuclei: multipole transitions, selection rules, life times, electron capture, internal conversion, isomers, Coulomb excitation.

UNIT - V

Nuclear Reactions: Kinematics, Q value, excitation energy, conservation laws, cross section, mean free path. Types of nuclear reactions, experimental observables, excitation function, angular distribution, spectra. Compound nuclear reactions, Resonances, level density, temperature, Bohr model. Direct nuclear reactions, optical model, pick up and stripping reactions, spectroscopic factor Nuclear fission and fusion reactions.

Suggested Texts and References:

1. Introductory Nuclear Physics, K.S. Krane, Wiley 2008

2. Concepts of Nuclear Physics, B. L. Cohen, McGraw Hill 1971

3. Introductory Nuclear Physics, S. S. M. Wong, Prentice - Hall 2010

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4. Introduction to Nuclear and Particle Physics, 2nd Edition, A. Das and T. Ferbel, World Scientific 2004

7.5 P704 Computational Physics - B (only for SEMESTER-VI students of session 2021-22)

UNIT - I

Introduction of Fortran programming Language, Random Number generation and testing, Generation of random numbers with given distribution

UNIT - II

Numerical Integration: (a) Deterministic: Trapezoidal method and (b) Multi-dimensional Integration using stochastic methods.

UNIT - III

Lattice Monte Carlo simulations using Ising model to understand phase transitions: Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations, Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations; Principle of detailed balance, calculating thermodynamic averages

UNIT - IV

Determining transition temperature using Binders cumulant, Solving differential equations, Linear, non-linear and coupled differential equations

UNIT - V

Solving differential equations Schrodinger equation. in Quantum Mechanics with Numerov's algorithm and variational principle., Classical Molecular Dynamics simulations using Lennard-Jones' potential

Suggested Texts and References:

1. Computational Physics: Problem Solving with Python, 3rd edition, Rubin H. Landau, Manuel J. Paez, Cristian C. Bordeianu
2. Computational Physics, Fortran Version, Steven E. Koonin, Dawn C.Meredith, CRC Press
3. Computational Physics,2nd edition, Jos Thijssen, Cambridge Univ. Press
4. Computational Physics, T. Pang
5. Computational Physics (An Introduction to Monte Carlo Simulations of Matrix Field Theory), Ydri, Badis
6. Computer Programing in F90 & 95, V. Rajaraman, PHI learning pvt. Ltd
7. Numerical Recipes in F90 Cambridge Publishers

16/01/2023

8. Computational Physics by Jos Thijssen (Cambridge UnivPress, 1997)
9. A first course in Computational Physics, P. L. DeVries and J. Hasbun, John Wiley and Sons. Inc.
10. Understanding Molecular Simulation, Publisher: Academic Press, Author: Daan Frenkel and Berend Smit

7.6 PL701: Advanced Physics Laboratory – I

Nuclear Physics

Spectral features of photoelectric absorption and Compton scattering with scintillation detectors (i) Inorganic: NaI(Tl), BaF2 (ii) Organic: BC501A and plastic. Energy calibration, energy resolution, photopeak and total efficiency, relative intensity, photoelectric and Compton cross- sections, radiation shielding. Alpha spectroscopy with a silicon surface barrier detector. Fine structure of alpha spectrum and determination of age of source. Fast timing and coincidence measurements using BaF2 and BC501A detectors. Angular correlation of gamma rays using NaI(Tl) detectors. High resolution, low-energy photon measurements with a silicon drift detector: Internal conversion studies, elemental composition through X-Ray Fluorescence (XRF) analysis. Geiger-Muller counter: operating characteristics, dead time measurement, determination of mass absorption coefficient, verification of inverse square law. Lifetime measurements: from nanoseconds through minutes using fast coincidence and decay studies. High-resolution gamma ray measurements with high-purity germanium detectors. Classic experiments: Rutherford scattering, cloud chamber, beta spectrometer. Spectrum analysis techniques and fitting routines: data/peak fitting, energy and efficiency calibration, 1D and 2D histograms. (Selected experiments from the above list are performed based on number of contact hours prescribed)

Condensed Matter physics

Growth of metallic thin films by physical vapor deposition techniques like thermal evaporation and DC magnetron sputtering. Tuning of growth parameters to change the deposition rate and hence thickness of the films. Introduction to vacuum techniques: vacuum pumps, rotary pump, diffusion pump and turbo molecular pumps. Measurement of vacuum: thermocouple gauges, hot and cold cathode gauges. Thickness measurement of thin films by quartz crystal monitor. Structural characterization of materials (some known and some unknown) by X-ray diffraction (XRD) and X-ray fluorescence (XRF) (a) Phase identification (b) Chemical composition (c) difference between powder diffraction pattern of single and polycrystalline systems (d) Reasons for line broadening in XRD: Rachinger correction and estimation of particle size from Debye- Scherer formula. (e) Identifying crystal structure and determination of lattice constant.

Introduction to low temperature measurements:

operation of a closed cycle cryostat, low temperature thermometers, controlling temperatures using PID feedback using temperature controllers, making electrical contacts on thin films and measuring DC resistance with sourcemeter using four probe method-advantages and disadvantages of the technique, temperature dependent (300-20K) measurement of electrical resistivity of metallic thin films and comparing the room temperature value with the standard. Determination of superconducting transition temperature of a high temperature superconductor using electrical transport measurements. Determination of band gap of a semiconductor: highly doped Si by fitting the temperature dependent resistance to the standard variation in semiconductors. Concepts of measuring electrical resistance in labs: from metals to dielectrics. Introducing GPIB interfacing of electronic instruments with the computer and writing LABVIEW programs to interface temperature controller and sourcemeter.

Introduction to phase sensitive measurements:

using of a dual phase lock-in amplifier. Measurement of the superconducting transition temperature of a superconducting thin film using a mutual inductance technique down to 2.6K (working of a cryogen free system). Measuring AC resistance of a milliohm resistor using phase sensitive detection and studying the frequency and amplitude variation of the resistance: introduction to noise, White noise and 1/f noise.

Suggested Texts and References:

1. Radiation Detection and Measurement, Glenn F. Knoll, John Wiley 2010
2. Techniques for Nuclear and Particle Physics Experiments: William R. Leo, Springer 1995
3. Basic Vacuum technology, 2nd Edition, A. Chambers, R. K. Fitch and B. S. Halliday, IOP 1998
4. Physical Vapor Deposition, R. J. Hill, McGraw-Hill 2005
5. Elements of X-ray Diffraction, 3rd Edition, B. D. Cullity and S. R. Stock, Prentice Hall 2001
6. Introduction to Solid State Physics, 8th Edition, C. Kittel, Wiley 2012.

7.7 PPr701: Reading Project

Reading project will be assigned by the supervisor.

SEMESTER - VIII

8.1 P801: Astronomy and Astrophysics

UNIT - I

Stellar Physics: Equations governing the structure of stars: Mechanical & Thermal equilibrium.Virial theorem. Modes of energy transfer in stars: radiative & convective transport of energy. Auxiliary input: equation of state, opacity and energy generation by thermonulcear processes. Boundary conditions at the stellar surface & at the centre.The main sequence, Stellar energy sources, Gravitational potential energy of a sphere, Gravitational lifetime for a star, Other energy sources, Nuclear energy for stars, Overcoming the fusion barrier, Stellar structure, Hydrostatic equilibrium, Energy transport, Stellar models, Solar neutrinos

UNIT - II

Stellar old age, Evolution off the main sequence, Low mass stars, High mass stars, Cepheid variables Variable stars, Cepheid mechanism, Period–luminosity relation, Planetary nebulae, White dwarfs, Electron degeneracy, Properties of white dwarfs, Relativistic effects

UNIT - III

The death of high mass stars, Supernovae , Core evolution of high mass stars, Supernova remnants Neutron stars, Neutron degeneracy pressure , Rotation of neutron stars, Magnetic fields of neutron stars, Pulsars, Discovery of Pulsars, What are pulsars? , Period changes, Pulsars as probes of interstellar space, Stellar black holes

UNIT - IV

THE MILKY WAY - OUR GALAXY: An overview of the Milky Way, The mass of the Milky Way, The disc of the Milky Way, The stellar halo and bulge of the Milky Way, The formation and evolution of the Milky Way, NORMAL GALAXIES: The classification of galaxies, The determination of the properties of galaxies, The determination of the distances of galaxies, The formation and evolution of galaxies, ACTIVE GALAXIES: The spectra of galaxies, Types of active galaxies, The central engine, Models of active galaxies, Outstanding issues

UNIT - V

Cosmology, The scale of the universe, Expansion of the universe, Olbers's paradox Keeping track of expansion, Cosmology and Newtonian gravitation, Cosmology and general relativity, Geometry of the universe, Cosmological redshift, Models of the universe, Is the universe open or closed?

16/01/2023

Suggested Texts and References:

1. **Text Book UNIT I to IV :** "Astronomy: A Physical Perspective" by Marc L. Kutner
2. **Text Book for UNIT V :** "An introduction to Galaxies and cosmology" Edited by Mark H.Jones and Robert J. Lambourne, Cambridge University Press.
3. **References:** The Internal Constitution of Stars, A. S. Eddington, Cambridge University Press, 1988.
4. An Introduction to the Study of Stellar Structure, S.Chandrasekhar, Dover Publications, 2003.
5. The structure & Evolution of the Stars, M.Schwarzschild, Dover Publications, 1962.
6. Cox and Giuli's Principles of Stellar Structure, 2nd Ed., A. Weiss et al., Cambridge, 2003.
7. The Physical Universe: An Introducing to Astronomy, F. H.Shu, University Science Books,1982.
8. Galactic Astronomy, James Binny and Michael Merrifield, Princeton University Press, 1998.
9. An Introduction to Active Galactic Nuclei, B. M. Peterson, Cambridge University Press, 1997.

8.2 P802: Fluid Mechanics

UNIT - I

Validity of hydrodynamical description. Kinematics of the flow field. Stress-strain relationship. Basic equations governing conservation of mass, momentum & energy.

UNIT - II

Navier-Stokes equation for viscous flows. Shear and bulk viscosity and radiative diffusivity in fluids. Viscous and thermal boundary layers, Potential flows, Water waves. Kelvin's circulation theorem, Stokes's flow Lubrication theory.

UNIT - III

Virial theorem in the tensor form. Magnetohydrodynamic flows. Generalized Ohm's law in the presence of Hall current &Ambipolar diffusion, Magneto-gravity-acoustic modes.

UNIT - IV

Classical hydrodynamic and hydromagnetic linear stability problems: Rayleigh-Taylor and Kelvin-Helmholtz instabilities. Jeans' gravitational instability; Benard convection. Parker instability and magnetic buoyancy. Thermal instability. Non-linear Benard problem.

UNIT - V

Spherical accretion flows onto compact objects and accretion disks. High Speed flow of gases. Shock waves and blast waves. Supernova hydrodynamics. Physiological hydrodynamics. Blood flow in human heart.

16/01/2023

Suggested Texts and References:

1. Hydrodynamics, 6th Edition, H. Lamb, Dover 1945
2. An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press, 2000
3. Fluid Mechanics, 2nd Edition, L.D. Landau and E.M. Lifshitz, Elsevier 1987

8.3 P803: Nuclear and Particle Physics

UNIT - I

Nuclear Reactions: Partial wave decomposition, phase shifts and partial wave analysis of the cross sections in terms of phase shifts. Behaviour of phase shifts in different situations. Black sphere scattering. Optical theorem and reciprocity theorem. Unitarity Optical potential: Basic definition. Relation between the imaginary part, W of the OP and σ abs, and between W and mean free path. Folding model and a high energy estimate of the OP.

UNIT - II

Catagorisation of Nuclear Reaction mechanisms: Low energies: Discrete region, Continuum Region: (a) Discrete Region: Decaying states. Relation between the width and the mean life time. Energy definition: Lorentzian or Breit- Wigner. Resonance scattering. Derivation of the resonance cross section from phase shift description of cross section. Transmission through a square well and resonances in continuum. Coulomb barrier penetration for charged particles scattering and centrifugal barrier for l non-zero states. Angular distributions of the particles in resonance scattering. Application to hydrogen burning in stars. (b) Continuum Region: Bohr's compound nucleus model.

UNIT - III

Direct Reactions: Cross section in terms of the T-matrix. Phase space, and its evaluation for simple cases. Lippmann Schwinger equation for the scattering wave function, and its formal solution. On-shell and off-shell scattering. Plane wave and distorted wave approximation to the Tmatrix(PWBA, DWBA). Application to various direct reactions like, stripping, pick-up, knockout etc.High energy scattering. Glauber theory. Eikonal approximation to the scattering wave function.Evaluation of scattering cross section in eikonal approximation. Introduction to heavyion scattering and the physics with radioactive ion beams.

UNIT - IV

Nuclear Structure: Generalization of the single-particle shell model, residual interactions, Fermi gas model. Single-particle energies in a deformed potential, shell corrections and the Strutinski method. Pairing: BCS model and the Bogolyubov transformation. Hartree-Fock method: general variational approach, Hartree-Fock equations and applications. Nuclear shape parametrization, quadrupole and higher- order deformations. Collective rotation and vibration; Giant resonances. Cranking model, phenomena at high spin including super-deformation. introduction to Density- Functional Models, including relativistic mean field. Selected contemporary research topics: Superheavy nuclei; Spectroscopy of drip-line nuclei.

16/01/2023

UNIT - V

Particle Physics: Symmetries and conservation laws, conserved quantities in reactions of particles. Relativistic kinematics in particle reactions, invariants, resonances, decays of resonances and their decays etc. Particle classification, mesons and baryons, SU(3) multiplets, quark model. Quarks, gluons, QCD interaction, colour neutrality. Detection of quarks and gluons, structure function in deep inelastic reactions. Quark and lepton families, weak interactions asguage theory, W and Z bosons. Symmetry breaking and generation of masses, Higgs bosons. Present boundary (strings, grand unification, matter- anti-matter asymmetry, dark matter and energy - seminar, qualitative)

Suggested Texts and References:

1. Subatomic Physics, E. M. Henley & A. Garcia, World Scientific
2. Concepts of Nuclear Physics, B. C. Cohen, McGraw-Hill.
3. Introduction to Nuclear and Particle Physics, A. Das and T. Ferbel, World Scientific.
4. Structure of the Nucleus: M.A. Preston and R.K. Bhaduri, Levant Books, 2008
5. Nuclear Models: W. Greiner and J.A. Maruhn, Springer, 1996
6. Nuclear Structure from a Simple Perspective: R. F. Casten, Oxford University Press, 1990
7. Theory of Nuclear Structure: M.K. Pal, Affiliated East-West Press, 1982
8. An Introduction to Quarks and Partons, F. E. Close, Academic Press 1980
9. Quarks and Leptons: An Introductory Course in Modern Particle Physics, F. Halzen and A. D. Martin, John Wiley 1984
10. Introduction to High Energy Physics, 4th Edition, D. Perkins, Cambridge 2000.

8.4 P804: Condensed Matter Physics – II

UNIT - I

Superconductivity: Revision, Introduction to second quantization, BCS theory, Electron tunneling and energy gap, Josephson effect (AC and DC). GL theory and concept of penetration depth, coherence length and surface energy, Flux quantization.

UNIT - II

Modified London Equation of Mixed Phase, Interaction between Flux tubes, Flux flow, Flux pinning, Magnetization of Mixed State: Bogoliubov transformation, Boundary between normal metal and superconductor, Andreev Reflection and Proximity effect.

UNIT - III

Magnetism: Quantum theory of magnetism: Rationalization of the Heisenberg Hamiltonian, Hubbard model and Stoner Model: Derivation of susceptibility, Spin wave using Holstein- Primakov transformation.

UNIT - IV

Introduction to Density Functional Theory Introduction to Special topics: Integer and Fractional Quantum hall effect, unconventional superconductivity, frustrated magnets, Josephson junction qubits, Graphene physics, Topological insulators.

UNIT - V

Kondo Physics, Metamaterials, Physics of photonic band gap materials, quantum cascade lasers, free electron lasers, organic electronics etc.

Suggested Texts and References:

1. Introduction to Superconductivity, 2nd Edition, M. Tinkham, Dover 2004
2. Superconductivity, J. B. Ketterson and S. N. Song, Cambridge 1999
3. Basic Solid State Physics by A. K. Raychaudhuri
4. Magnetism in Solids, D. H. Martin, Butterworth 1967
5. Quantum theory of Magnetism, 3rd Edition, R. M. White, Springer 2006
6. Electronic Structure, Basic Theory & Practical Methods, R. Martin, Cambridge 2008.

8.5 PL801: Advanced Physics Laboratory – II

Introduction to Observational Astronomy:

Transmission of radiation through atmosphere in different bands, need for space platforms for invisible astronomies, Introduction to Optical, Infrared, Ultra-violet, X-ray and Gamma-ray astronomy, what do me measure and learn from different wavebands.

Introductory Astronomy and Different types of Optical Telescopes:

Astronomical parameters like Apparent and Absolute magnitude, Flux, Luminosity and its dependence on size and temperature of stars, Atmospheric Extinction, Coordinate System in Astronomy Refracting and Reflecting telescopes, different focal plane configurations, their applications and relative merits and demerits. Reflectivity and its wavelength dependence, "seeing" and factors affecting it, use of active and adaptive optics in modern telescopes to overcome atmospheric and thermal effects, calculation of focal length, focal ratio, magnification, field of view, plate scale, diffraction limit of telescopes.

Introduction to Focal Plane Detectors for Optical, infrared and UV astronomy:

Developments and evolution of modern Optical and Infrared imaging detectors: Photographic Plates, Phototubes, Image Intensifiers, Charge Coupled Devices (CCDs), Bolometers and how they work, their characterization and parameters (charge transfer efficiency, quantum efficiency, flat fielding etc.). CCDs uses in Imaging, morphological and Spectroscopic studies, Infrared Detectors and IR Arrays, UV Imaging and Photon Counting Detectors.

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Different types of Focal Plane Instruments:

Imagers, Photometers, Fast Photometers for photon counting, limitations of PMT and CCD bases photometers, Importance of spectroscopy, Design and description of Low and High Resolution Spectrometers and their applications, Polarimeters and their applications.

Interaction of radiation with matter:

(a) Passage of charged and neutral particles through matter, Ionization loss formulae and dependence on different parameters, relativistic rise in ionization loss, detection of neutrons, Bremsstrahlung process, Cerenkov radiation and its application (b) Interaction of photons with matter: Photoelectric interaction, mass absorption formula and dependence on energy, atomic number etc, Thompson scattering, Compton scattering, Pair production process, formula and dependence on energy, atomic number, radiation length, critical energy

Introduction to Different Types of Gas-Filled Radiation Detectors:

Role of development of new detection techniques in new discoveries in high energy physics and astrophysics, different kind of detection techniques for charged and neutral radiation Dependence of charge multiplication on high voltage and pressure, Townsend coefficient, need for use of inert gases, quench gas, mobility of electrons and ions (a) Ionization Chamber (IC), description of a typical IC, its characteristics, application of IC in physics (b) Proportional Counters (PC): Single and multi cell PCs, filling gases, Penning effect, charge multiplication process, energy resolution of PC, Fano factor, use of PCs in high energy physics, and astronomy especially in X-ray astronomy (c) Geiger Mueller (GM)Counter: Typical GM counter, its characteristics, applications of GM counter

Scintillation Counters, Cerenkov Detectors and other Solid State Detectors:

Scintillation processes, dependence on energy, charge and atomic number, Photomultiplier (PMT) for detection of light, PMT characteristics, charge multiplication and use of PMTs with scintillators (a) Organic Scintillation Counters: Plastic Scintillators and light yield, their use in charged particle detection, a typical PS detector and its characteristics (b) Inorganic Scintillation Counters: Scintillation medium and need for activators, Sodium Iodide (NaI) and Caesium Iodide detectors, their light output, application of these detectors in physics and astrophysics (c) Silicon detectors and their applications in X-ray Astronomy, Germanium Detectors, Cadmium -Telluride devices and their arrays

Observational X-ray Astronomy:

Birth and evolution of X-ray Astronomy, different types of X-ray sources, Discovery of X-ray Binaries, their broad properties, optical identification, classification in Low Mass X-ray binaries (LMXBs) and High Mass X-ray Binaries (HMXBs), their unique characteristics, estimation of mass of the compact star in X-ray binaries from the binary parameters (a) Neutron Star Binaries (NSB): X-ray Pulsars in Binaries, Rotation powered pulsars in SNRs, detailed discussion of their timing and spectral properties, New physics and astrophysics learnt from their studies (b) Black Hole Binaries (BHB): Inference about black hole nature, time variability, spectral measurements, mass of black hole

X-ray Radiation Processes:

(a) Thermal Emission, Black Body emission, Thermal Bremstrahlung (free-free emission),spectral line formation in thermal plasma, examples of thermal spectra, measurement of temperature and elemental abundances from spectral data (b) Non-thermal Emission: Synchrotron mechanism (magnetic bremstrahlung), spectral shape, polarized emission, Inverse Compton Scattering, spectrum of radiation, examples of non-thermal spectra, Cyclotron process in strongly magnetized stars and formation of cyclotron lines, determination of magnetic field of the stars

Experiments to be performed:

1. Measuring energy resolution (R) of a Cadmium Telluride Detector using X-rays of different energies (E) from radioactive sources and deriving expression for variation of R with E.
2. Solar Constant measurement.
3. Measurement of Solar Limb Darkening.
4. Observing an Optical Binary Star and deriving its light curve.
5. Determine Pulsation period and binary light curve of an accreting Neutron star from X-ray data.
6. Measuring X-ray Energy Spectrum of a Black Hole Binary and fit it with different spectral models.
7. Characteristics of a Proportional Counter and dependence of its energy resolution on different parameters of the PC.

8.6 PPr801: Project

Project will be assigned by the supervisor.

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SEMESTER - IX

9.1 PPr901: Project

Project will be assigned by the supervisor.

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SEMESTER - X

10.1 PE - 1: Quantum Field Theory

UNIT - I

Preliminaries: Why Quantum Field Theory, Creation and annihilation operators, Special relativity, Space and time in relativistic quantum theory, natural units

UNIT - II

Canonical Quantization: General Formulation. Conjugate Momentum and Quantization. Neutral Scalar Field. Commutation Relations, Normal Ordering, Bose Symmetry, Fock Space. Charged Scalar Field. U(1) Invariance, Charge Conservation, Particles and Antiparticles. Time Ordered Product, Feynman Propagator for Scalar Fields, Bose- Einstein Distribution, Propagators at Finite Temperature.

UNIT - III

Dirac Field: The Dirac Equation, Relativistic Covariance. Anti-Commutators. Quantization of the Dirac Field, Electrons and Positrons. Connection between Spin and Statistics. Discrete Symmetries, Parity, Charge Conjugation, Time Reversal, CPT Theorem.

UNIT - IV

Gauge Field: Gauge Invariance and Gauge Fixing. Quantization of the Electromagnetic Field, Propagator, Vacuum Fluctuations.

UNIT - V

Interacting Theory and Elementary Processes: Wick's Theorem. Feynman Rules and Feynman Diagrams for Spinor Electrodynamics, Lowest Order Cross-Section for Electron-Electron, Electron-Positron and Electron- Photon Scattering.

Suggested Texts and References:

1. Quantum Field Theory, C. Itzykson and J. B. Zuber, McGraw-Hill Book Co, 1985.
2. Quantum Field Theory, L. H. Ryder, Cambridge University Press, 2008.
3. Field Theory, A Modern Primer, P. Ramond, Benjamin, 1980.
4. The Quantum Theory of Fields, Vol I, S. Weinberg, Cambridge University Press, 1996.

5. Introduction to The Theory of Quantum Fields, N. N. Bogoliubov and D. V. Shirkov, Interscience, 1960.

6. An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder, Westview Press, 1995.

7. Quantum Field Theory: Mandl and Shaw

8. A first book of Quantum Field Theory, Amitabha Lahiri, Palash B. Pal, Alpha Science International Ltd., 2000

10.2 PE - 2: General Relativity and Cosmology

UNIT - I

Review of Newtonian Mechanics. Special theory of relativity. Prelude to General relativity, historical developments, 4-Vectors and 4-tensors, examples from physics

UNIT - II

Principle of Equivalence, Equations of motion, Gravitational force, Tensor Analysis in Riemannian space, Effects of Gravitation, Riemann-Christoffel curvature tensor, Ricci Tensor, Curvature Scalar, Einstein Field Equations, Experimental tests of GT, Scwartzchild Solution,

UNIT - III

Introduction to Cosmology, The cosmic history and inventory, The expanding Universe

UNIT - IV

Friedmann Equations and Cosmological Models, The Standard cosmological model, The inflationary Universe, Big-Bang Hypothesis

UNIT - V

Primordial nucleosynthesis and the thermal history of the Universe. Perturbations in an expanding Universe, Growth of perturbations, Dark Matter Halos

Suggested Texts and References:

1. A first course in General Relativity- B. Schutz

2. Gravity: HJ. Hartle

3. The Classical Theory of Fields: Landau and Lifshitz

4. Gravitation and Cosmology: S. Weinberg5. Introducing Einstein's Relativity: D'Inverno

5. Introducing Einstein's General Relativity - Ray D'Inverno

6. The Early Universe - Kolb and Turner

7. Introduction to Cosmology - Barbara Ryden
8. Modern Cosmology - Scott Dodelson
9. Principles of Physical Cosmology - P.J.E. Peebles
10. Large Scale Structure of the Universe - P.J.E. Peebles
11. Structure Formation in the Universe - T. Padmanabhan

10.3 PE - 3: Experimental Techniques

UNIT – I

Vacuum technology: gases, gas flow, pressure and flow measurement, vacuum pumps, pumping mechanisms, ultrahigh vacuum, leak detection

UNIT – II

Optical systems: optical components, optical materials, optical sources Charge particle optics: electrostatic lenses, charged-particle sources, energy and mass analyzer

UNIT – III

Detectors: optical detectors, photoemission detectors, particle and ionizing radiation detectors, signal to noise ration detection, surface barrier detector.

UNIT – IV

Particle detectors and radioactive Decay: Interactions of charged particles and photons with matter; gaseous ionization detectors, scintillation counter, solid state detectors

UNIT – V

Electronics: electronic noise, survey of analog and digital I/Cs, signal processing, data acquisition and control systems, data analysis evaluation

Suggested Texts and References:

1. The art of Measurement, by Bernhard Kramer, VCH publication
2. Building Scientific apparatus by J. H. Moore et al.
3. Experiments in Modern Physics, Second Edition by Adrian C. Melissinos, Jim Napolitano
4. Vacuum Technology, A. Roth North-Holland Publisher
5. Charge Particle Beams, by Stanley Humphries, John Wiley and Sons
6. Principles of charged Particles Acceleration, by Stanley Humphries, John Wiley and Sons
7. Radiation detection and Measurements, G. Knoll, 3rd Edition

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8. Techniques for Nuclear and particles physics experiments, W. R. Leo, 2nd edition, Springer

9. The Physics of Micro & Nanofabrication, Ivor Brodie,and Julius J. Muray, Springer

10. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R.Egerton, Springer, 2005

11. Egerton, Springer, 2005Modern Spectroscopy, J. M. Hollas, John Wiley, 4th Edition, 2004

10.4 PE - 4: CCD Imaging and Spectroscopy

UNIT - I

Introduction : Why use CCDs?, CCD manufacturing and operation, CCD operation, CCD types, CCD coatings, Analog-to-digital converters

UNIT - II

Characterization of charge-coupled devices: Quantum efficiency, Charge diffusion, Charge transfer efficiency, Readout noise, Dark current, CCD pixel size, pixel binning, full well capacity, and windowing, Overscan and bias, CCD gain and dynamic range,

UNIT - III

CCD imaging, Photometry and astrometry: Image or plate scale, Flat fielding, Calculation of read noise and gain, Signal-to-noise ratio, Basic CCD data reduction, CCD imaging, Stellar photometry from digital images, Two-dimensional profile fitting, Difference image photometry, Aperture photometry, Absolute versus differential photometry, High speed photometry, PSF shaped photometry, Astrometry, Pixel sampling

UNIT - IV

Review of spectrographs: CCD spectrographs, CCD spectroscopy, Signal-to-noise calculations for spectroscopy, Data reduction for CCD spectroscopy, Extended object spectroscopy, Slitless spectroscopy

UNIT - V

CCDs used in space and at short wavelengths : CCDs in space, Radiation damage in CCDs, CCDs in the UV and EUV (300–3000 Å) spectral range, CCDs in the X-ray, (< 500 Å) spectral range

Suggested Texts and References:

1. Handbook of CCD Astronomy, Second edition S. B. Howell

2. Stellar Magnitudes from Digital Pictures, Adams, M., Christian, C., Mould, J., Stryker, L., & Tody, D., 1980, Kitt Peak National Observatory publication

3. The Next Generation Space Telescope, Bely, P.-Y., Burrows, C., & Illingworth, G. (eds.), 1989, Space Telescope Science Institute publication.

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4. Blouke, M., Yang, F., Heidtmann, D., & Janesick, J., 1988, in Instrumentation for Ground-Based Optical Astronomy, ed. L. B. Robinson, Springer-Verlag, p. 462.

5. Bonanno, G., 1995, in New Developments in Array Technology and Applications, eds. A. G. D. Philip, K. A. Janes, & A. R. Upgren, Kluwer, p. 39.

6. Born, M. & Wolf, E., 1959, Principles of Optics, MacMillan, Chap. VIII.

7. Bowen, I. S., 1960a, in Astronomical Techniques, ed. W. A. Hiltner, University of Chicago Press, Chap. 2.

8. Brown, R. (ed.), 1993, The Future of Space Imaging, Space Telescope Science Institute publication, Chap 8.

10.5 PE - 5: Biophysics

UNIT - I

Mathematical Methods in Biophysics : Functions of One Variable and Ordinary Differential Equations, Functions of Several Variables: Diffusion Equation in One Dimension., Random Walks and Diffusion, Random Variables, Probability Distribution, Mean, and Variance , Diffusion Equation in Three Dimensions., Complex Numbers, Complex Variables, and Schrodinger's Equation , Solving Linear Homogeneous Differential Equations., Fourier Transforms, Nonlinear Equations: Patterns, Switches and Oscillators

UNIT - II

Quantum Mechanics Basic to Biophysical Methods: Quantum Mechanics Postulates, . One-Dimensional Problems, The Harmonic Oscillator, The Hydrogen Atom, Approximate Methods, Many Electron Atoms and Molecules , The Interaction of Matter and Light

UNIT - III

Computational Modeling of Receptor–Ligand Binding and Cellular Signaling Processes: Differential Equation-Based Mean-Field Modeling, Application: Clustering of Receptor–Ligand Complexes, Modeling Membrane Deformation as a Result of Receptor–Ligand Binding, Limitations of Mean-Field Differential Equation-Based Modeling, Master Equation: Calculating the Time Evolution of a Chemically Reacting System,

UNIT - IV

Stochastic Simulation Algorithms: Stochastic Simulation Algorithm (SSA) of Gillespie, Application of the Stochastic Simulation Algorithm (SSA), Free Energy-Based Metropolis Monte Carlo Simulation, Application of Metropolis Monte Carlo Algorithm, Stochastic Simulation Algorithm with Reaction and Diffusion: Probabilistic Rate Constant–Based Method,Mapping Probabilistic and Physical Parameters, Modeling Binding between Multivalent Receptors and Ligands, Multivalent Receptor–Ligand Binding and Multi-molecule Signaling Complex Formation, Application of Stochastic Simulation Algorithm with Reaction and Diffusion,Choosing the Most Efficient Simulation Method

UNIT - V

Fluorescence Spectroscopy: Fundamental Process of Fluorescence, Fluorescence Microscopy, Types of Biological Fluorophores, Application of Fluorescence in Biophysical Research, Dynamic Processes Probed by Fluorescence Electrophysiological Measurements of Membrane Proteins : Membrane Bio-electricity, . Electrochemical Driving Force, Voltage Clamp versus Current Clamp, Principles of Silver Chloride Electrodes, Capacitive Current and Ionic Current.Gating and Permeation Functions of Ion Channels, Two-Electrode Voltage Clamp for Xenopus Oocyte Recordings , Patch-Clamp Recordings , Patch-Clamp Fluorometry

Suggested Texts and References:

1. Fundamental Concepts in Biophysics, Thomas Jue
2. Alon U. 2006. An introduction to systems biology: design principles of biological circuits. Boca Raton: Chapman & Hall.
3. Berg HC. 1993. Random walks in biology. Princeton: Princeton UP.
4. Nelson P. 2004. Biological physics: energy, information and life. New York: W.H. Freeman and Company.
5. Van Kampen NG. 1992. Stochastic processes in physics and chemistry. Amsterdam: North Holland.
6. Shankar R. 1994. Principles of quantum mechanics. New York: Plenum.
7. Cohen-Tannoudji C, Diu B, Laloe F. 1977. Quantum mechanics. Trans SR Hemley, N Ostrowsky, D Ostrowsky, New York: Wiley.
8. Lauffenburger DA, Linderman JJ. 1993. Models for binding, trafficking and signaling. Oxford: Oxford UP.
9. Fall CP, Marland S, Wagner JM, Tyson JJ, eds. 2002. Computational cell biology. New York: Springer

10.6 PE - 6: Particle Physics

UNIT - I

Elementary particles, discrete symmetries and conservation laws, Symmetries and Quarks.

UNIT - II

Klein-Gordon equation, concept of antiparticle, Lorentz symmetry and scalar / vector / spinor fields.

UNIT - III

Dirac equation, Scattering processes of spin-1/2 particles (Feynmans rules as thumbrule QFT course), propagators.

UNIT - IV

Current-current interactions, weak interaction, Fermi theory, Gauge symmetries, spontaneous symmetry breaking, Higgs mechanism

UNIT - V

Electroweak interaction, Glashow-Salam-Weinberg model, Introduction to QCD, structure of hadrons (form factors, structure functions), parton model, Deep inelastic scattering.

Suggested Texts and References:

References: 1. Quarks and Leptons: An Introductory Course in Modern Particle Physics - FrancisHalzen, Alan D. Martin 2. Introduction to Elementary Particles, David Griffiths 3. Concepts of Particle Physics, Volume I, Kurt Gottfried and Victor F. Weisskopf, 1986, Oxford University Press, 4. Classical Electrodynamics second edition, J.D. Jackson, 1975, John Wiley & Sons, Inc., (chapters 11 and 12) 5. Introduction to High Energy Physics, fourth edition, Donald H. Perkins, 2000, Cambridge University Press, 6. Experimental Techniques in High Energy Physics, Thomas Ferbel (editor), 1987, Addison Wesley 7. Gauge Theory of Elementary Particle Physics, Ta-Pei Cheng and Ling-Fong Li, 1984, Oxford University Press 8. Weak Interactions of Leptons and Quarks, E.D. Commins and P.H. Bucksbaum, 1983, Cambridge University Press

10.7 PE - 7: Nonlinear Dynamics and Chaos

UNIT - I

Dynamical Systems, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps. Fixed points, linearization of vector fields, canonical forms, generalized eigenvectors, semisimple – nilpotent decomposition, Jordan canonical form.

UNIT - II

Classification of fixed points. Hartman -Grobman theorem, homeomorphism, Stable Manifold Theorem, Centre Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Dynamical Systems, phase portraits, vector fields, nullclines, flows, discrete dynamical systems, 1-d maps, Fixed points.

UNIT - III

Linearization of vector fields, canonical forms, generalized eigen vectors, semisimple-nilpotent decomposition, Jordan canonical form, classification of fixed points. Hartman-Grobman theorem, homeomorphism, Stable Manifold Theorem, Centre Manifold Theorem, examples of manifolds. Index theory, Lyapunov functions and stability analysis, Limit cycles, Poincare-Benedixon Theorem. Gronwall's inequality.

UNIT - IV

The Variational Equation, exploring neighbourhoods, Lyapunov exponents, Monodromy matrix, Floquet exponents. Bifurcations: Saddle-Node, Transcritical, Pitchfork and Hopf Bifurcation. 1-d maps, linear stability of fixed points and higher order fixed points, chain rule, lyapunov exponent, bifurcation diagram, finding period-n orbits in 1-d maps. 2-d maps, Linearization, the Henon map.

UNIT - V

Poincare surface of section. Symbolic dynamics, Sensitivity to initial conditions, Chaos, Partitions, Transition matrix, Entropies, Smale Horseshoe. Invariant density, the Perron-Frobenius operator. Fractals. Hamiltonian Dynamics.

Suggested Texts and References:

1. Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry and Engineering, S. Strogatz, Addison-Wesley 2001
2. Chaos: An Introduction to Dynamical Systems, K.T. Aligood, T.D. Sauer, J.A. Yorke, Springer 2000
3. Differential Equations, Dynamical Systems and an Introduction to Chaos, M. Hirsh, S. Smale and R. Devaney, Elsevier Academic Press, 2012
4. Chaos and Integrability in Nonlinear Dynamics: An Introduction, M. Tabor, John Wiley & Sons,1989
5. Chaos: Classical and Quantum, P. Cvitanovic et al.

10.8 PE - 8: Reactor Physics and Radiation Science

UNIT - I

Fission process: Liquid drop model, fission rate, reactor power, prompt and delayed neutrons, fission gammas, fission products energy balance, photo neutrons. fissile, fertile and fissionable materials. Fission product activity and decay heat after shut down. Interaction of Neutrons with Matter: Production of neutrons and nuclear reactions with thermal and fast neutrons, transmutation.

UNIT - II

Concept of microscopic cross section: Inelastic and elastic scattering, Maxwell-Boltzmann distribution and its departure Variation of cross-section with energy, fast, resonance and thermal ranges. 1/v law of neuron cross-section, Resonance absorption, Doppler effect. Eta vs E curve, conversion & breeding concepts-Thorium utilization. Diffusion of neutrons: Fick's law and its validity, steady state neutron diffusion equation, concepts of neutron flux and current, interface conditions, diffusion coefficient, diffusion lengthand extrapolation distance.

UNIT - III

Chain Reaction: Four Factor formula, conceptual treatment of diffusion of one group neutrons in non multiplying and multiplying media, infinite and effective multiplication factors bare homogeneous reactor-concepts of material and geometric buckling, sub criticality and super criticality, critical mass, non leakage probabilities in bare homogeneous cores, neutron cycle and lifetime in finite and in infinite reactor system. Slowing down process: Neutron slowing down, slowing down power and moderating ratio for moderators. Slowing down with spatial migration, Fermi age concepts, migration length, use of reflectors/blankets, reflector savings. Heterogeneous reactors: Multigroup neutron diffusion with special reference to 2 group approach, Heterogeneous reactors, comparison with homogeneous reactors, unit cell concepts.

UNIT - IV

Reactor kinetics: Time dependent neutron diffusion equation, one group kinetic equation, prompt neutron life time, Point kinetic model to illustrate importance of delayed neutrons, reactor period, reactivity and its units. Fuel burn-up units. Neutron Poisons: Xenon and Samarium Poisons, Xenon loads (operating and post shutdown), Variation of xenon load with power and enrichment. Xenon oscillations and their control.

UNIT - V

Reactivity coefficients: Temperature coefficients of reactivity and void coefficient of reactivity, their relevance to reactor safety. techniques to control reactors, typical reactivity balance, longterm burnup, fuel management. Reactor control system – requirements of physics aspects. Reactor shutdown mechanisms and neutron monitoring during operation and shut down. Approach to criticality, physics measurements and calibrations/validations. Reactivity worth measurements of control rods. Research Reactors at Trombay, Indian PHWRs.

Suggested Texts and References:

1. Nuclear Reactor Engineering: Reactor Systems Engineering, Samuel Glasstone and Alexander Sesonske, 4th Edition, 2012
2. Introduction to Nuclear Engineering, 3rd Ed., John R. Lamarsh and Anthony J. Baratta, 2001.
3. Nuclear Reactor Analysis, James J. Duderstadt and Louis J. Hamilton, 1976
4. Nuclear Energy: An Introduction to the Concepts, Systems, and Applications of Nuclear
5. Processes, 6th Ed., Raymond Murray and Keith E. Holbert, 2008.
6. Fundamentals of Nuclear Reactor Physics, Elmer E. Lewis, 2008.
7. Nuclear Reactor Physics, 2nd Ed., Weston M. Stacy, 2007
8. Nuclear Energy: Principles, Practices and Prospects, David Bodansky, 2008.

10.9 PE - 9: Accelerator Physics and Applications

UNIT - I

Transverse beam dynamics: Accelerator coordinates; Canonical transformation to accelerators coordinates; Guide field; Dipole and Quadrupole Magnets; Hills equation and solution; Twiss parameters; Matrix formulation; Dispersion; Design of lattices; Field and gradient errors; Chromaticity; sextupole magnets and dynamics aperture.

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UNIT - II

Longitudinal beam dynamics: Fields and forces; acceleration by time varying fields; relativistic equations; Overview of acceleration; transit time factor; main RF parameters; momentum compaction factor; transition energy; Equations related to synchrotron; synchronous particle; synchrotron oscillations; principle of phase stability; RF acceleration for synchronous and for non-synchronous particle; small amplitude oscillations; Oscillations with Hamiltonian formalism; limits of stable region; adiabatic damping.

UNIT - III

Linear accelerators: Basic methods of linear acceleration; Fundamental parameters of accelerating structures; Energy gain in linear accelerating structures; Q, Shunt-impedance, transit-time factor; periodic accelerating structures; RFQs; Microwave topics for linacs; Single particle dynamics in linear accelerators; Multi-particle dynamics in linear accelerators.

UNIT - IV

Synchrotron radiation: Introduction to electromagnetic radiation; Radiation of accelerated charged particles; radiation from wigglers and undulators; Electron dynamics with radiation; Low emittance lattices; synchrotronradiation sources.

UNIT - V

Free-electron lasers: Introduction; electron dynamics in the undulator; spontaneous emission; electron dynamics in the laser field; dynamics of the laser field; dimensionless equations of motion; solution in the small-signal, small-gain regime; Madey theorem; three-dimensional effects; undulators; X-ray laser. Advanced accelerator concepts: Photo injectors; laser-wakefield acceleration; plasma-wakefield acceleration; linear colliders; muon colliders.

Suggested Texts and References:

1. An Introduction to the Physics of High-Energy Accelerators, D. A. Edwards & M. J. Syphers
2. An Introduction to Particle Accelerators, Edmund Wilson
3. Introduction to Accelerator Physics, Arvind Jain
4. R. F. Linear Accelerators, T. P. Wangler
5. Classical Electrodynamics, 3rd Edition, J. D. Jackson, Wiley 2012

10.10 PE - 10: Computational Physics - C

UNIT - I

Introduction of Fortran programming Language, Random Number generation and testing, Generation of random numbers with given distribution

UNIT - II

Numerical Integration: (a) Deterministic: Trapezoidal method and (b) Multi-dimensional Integration using stochastic methods.

UNIT - III

Lattice Monte Carlo simulations using Ising model to understand phase transitions: Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations, Metropolis algorithm, understanding kinetic barriers, finite size effects, role of thermal fluctuations; Principle of detailed balance, calculating thermodynamic averages

UNIT - IV

Determining transition temperature using Binders cumulant, Solving differential equations, Linear, non-linear and coupled differential equations

UNIT - V

Solving differential equations Schrodinger equation. in Quantum Mechanics with Numerov's algorithm and variational principle., Classical Molecular Dynamics simulations using Lennard-Jones' potential

Suggested Texts and References:

1. Computational Physics: Problem Solving with Python, 3rd edition, Rubin H. Landau, Manuel J. Paez, Cristian C. Bordeianu
2. Computational Physics, Fortran Version, Steven E. Koonin, Dawn C.Meredith, CRC Press
3. Computational Physics,2nd edition, Jos Thijssen, Cambridge Univ. Press
4. Computational Physics, T. Pang
5. Computational Physics (An Introduction to Monte Carlo Simulations of Matrix Field Theory), Ydri, Badis
6. Computer Programing in F90 & 95, V. Rajaraman, PHI learning pvt. Ltd
7. Numerical Recipes in F90 Cambridge Publishers
8. Computational Physics by Jos Thijssen (Cambridge UnivPress, 1997)
9. A first course in Computational Physics, P. L. DeVries and J. Hasbun, John Wiley and Sons. Inc.
10. Understanding Molecular Simulation, Publisher: Academic Press, Author: Daan Frenkel and Berend Smit

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10.11 PE - 11: Glimpses of Contemporary Sciences

UNIT - I

Physics in life systems: size and scale, diffusion, cell locomotion, force generated by acting growth and flagellum rotatory motion, ion channels, resting potential across the membrane, nerve conduction velocity, action potential, macromoleculaes of life, random walk model of polymer, single molecular experiments, optical tweezers, magnetic tweezers.

UNIT - II

Complex systems: dynamical chaos, logistic map, bifurcation, Universality, Feigenbaum constants, Mechanical demonstrations of chaos,Nanomechanical oscillators, Patterns,Reaction-diffusion systems, Nodal patterns, thermodynamics and human population, Falling leaves, Smoke ring physics.

UNIT - III

At the turn of 1900: Silver threads, Discovery of the electron, Rutherford's nuclear atom Wien's law, Blackbody radiation and Max Planck's action.

UNIT - IV

Astrophysics, Astrochemistry and Astrobiology

UNIT - V

Quantum mechanics, atoms : Entanglement Light-atom interaction, Bringing atoms to rest, Laser tweezers, How bright is laser, Quantum computing.

Suggested Texts and References:

1. "Growth and Forms" by Darcy Wentworth Thompson
2. "Physical biology of the cell" by Rob Phillips
3. "Random walks in biology" by Harward Berg
4. "Physics: Structure and Meaning" by L. Cooper
5. "The Feynman Lectures on Physics vol. 3" by R.P.Feynman, R.B.Leighton and M. Sands

10.12 PE - 12: Earth Science and Energy & Environmental Sciences

UNIT - I

Earth Science:
Origin of the earth, type of rocks in different layers, their physical and chemical properties, mechanism of their formation and destruction. Radioactivity and its role in geochronology, Plate tectonics and geodynamics and the role of mantle plumes in sustaining these processes.

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UNIT - II

Gravity,electrical and magnetic properties of the different layers in the earth. Their variations in different geological terrains. Instrumentation, field procedures used in these studies. Response of the earth to the elastic (Seismic) and electromagnetic waves, use of this phenomena to study the earth's interior.

UNIT - III

Geodynamo and the internal magnetic field of the earth. Paleomagnetic studies, Polar wandering and reversal, possible theoretical arguments for understanding the phenomena. Seismology and its use in understanding of the different layers in the earth's interior. Utility of the different geophysical techniques (discussed above) in exploration for academic as well as for harnessing resources.

UNIT - IV

Energy and Environmental Sciences:
Introduction to Environmental Science. Natural Environments: Ecosystems and ecology, biodiversity. Socio-cultural environments: demography, population density, human organizations. Land use and its planning. Global climate change and effects on environment. Carbon cycle from human activity, calculation of carbon budgets. Water harvesting, storage and treatment. Natural calamities, hazards, and effects of human activity: Chemical and other technological hazards. Various case studies of natural calamities and human-induced disasters. Causes, effects, forecasting, preparedness, planning measures, technological solutions, social interventions. Concept of sustainability, individual and social, and local and global actions for a sustainable future.

UNIT - V

Introduction to energy Sources - evolution of energy sources with time. Power production, per capita consumption in the world, and relation to development index. Energy scenario in India: Various issues related to consumption and demands -energy crisis issues in India. Renewable and non-renewable energy sources - technology and commercialization of energy sources, local (decentralized) versus centralized energy production, constraints and opportunities of renewable energy (hydrocarbon and coal based energy sources). Energy conservation – calculation of energy requirements for typical and home and industrial applications. Alternative to fossil fuels - solar, wind, tidal, geothermal. Bio-based fuels. Hydrogen as a fuel. Energy transport and storages,comparison of energy sources - passage from source to delivery (source, production, transport,delivery) - efficiencies, losses and wastes. Nuclear energy: Power production: Components of a reactor and its working, types of reactors and comparison. India's three stage nuclear program. Nuclear fuel cycle. Thorium based reactors. Regulations on nuclear energy.

Suggested Texts and references:

1. The magnetic field of the Earth, Merill, R.T. McElhinny, M.W. and McFadden, P.L.International Geophysical Series.

2. Earth Science by Edward J. Tarbuck, E.J. and Lutgens, F.K.

3. Introduction to Applied Geophysics: Exploring the Shallow Subsurface Burger, H.R., Sheehan, A.F., C.H.

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4. Mantle Plumes and Their Record in Earth History, Condie, K.C., 2001, Cambridge University Press, Cambridge, UK

5. Applied Geophysics (Paperback) W M Telford, Robert E Sheriff and L P Geldart.

6. Energy in Perspective, J. B. Marion, University of Maryland, Academic Press, (1974)

7. Energy and Environment, Robert A. Ristinen and Jack J. Kraushaar, 2nd Edn., John Wiley and Sons, Inc. (2006).

8. Renewable Energy, Boyle Godfrey, Oxford University Press (2004)

9. Environment, Problems and Solutions, D.K. Asthana and Meera Asthana, S.Chand and Co.(2006)

10. Text Book on Environmental Chemistry, Balaram Pani, I.K.International Publishing House(2007).

10.13 PE - 13: Circuits and Electronics

UNIT - I

Analysis of Nonlinear Circuits: Introduction to Nonlinear Elements, Analytical Solutions, Graphical Analysis, Piecewise Linear Analysis, Improved Piecewise Linear Models for Nonlinear Elements, Incremental Analysis
The Digital Abstraction: Voltage Levels and the Static Discipline, Boolean Logic, Combinational Gates, Standard Sum-of-Products Representation, Simplifying Logic Expressions, Number Representation

UNIT - II

The MOSFET Switch: The Switch, Logic Functions Using Switches, The MOSFET Device and Its S Model, MOSFET Switch Implementation of Logic Gates, Static Analysis Using the S Model, The SR Model of the MOSFET, Physical Structure of the MOSFET, Static Analysis Using the SR Model, Static Analysis of the NAND Gate Using the SR Model, Signal Restoration, Gain, and Nonlinearity, Signal Restoration and Gain, Signal Restoration and Nonlinearity, Buffer Transfer Characteristics and the Static Discipline, Inverter Transfer Characteristics and the Static Discipline, Power Consumption in Logic Gates, Active Pull-ups
The MOSFET Amplifier : Signal Amplification, Review of Dependent Sources, Actual MOSFET Characteristics, The Switch-Current Source (SCS) MOSFET Model, The MOSFET Amplifier, Biasing the MOSFET Amplifier, The Amplifier Abstraction and the Saturation Discipline, Large-Signal Analysis of the MOSFET Amplifier, v_{IN} Versus v_{OUT} in the Saturation Region, Valid Input and Output Voltage Ranges, Alternative Method for Valid Input and Output Voltage Ranges, Operating Point Selection, Switch Unified (SU) MOSFET Model
The Small-Signal Model: Overview of the Nonlinear MOSFET Amplifier, The Small-Signal Model, Small-Signal Circuit Representation, Small-Signal Circuit for the MOSFET Amplifier, Selecting an Operating Point, Input and Output Resistance, Current and Power Gain.

UNIT - III

Energy Storage Elements: Constitutive Laws, Capacitors, Inductors, Series and Parallel Connections, Capacitors, Inductors, MOSFET Gate Capacitance, Wiring Loop Inductance, IC Wiring Capacitance and Inductance, Transformers, Sinusoidal Inputs, Step Inputs, Impulse Inputs, Role Reversal, Energy,

Charge, and Flux Conservation.
First-Order Transients in Linear Electrical Networks, Analysis of RC Circuits: Parallel RC Circuit, Step Input; RC Discharge Transient; Series RC Circuit, Step Input; Series RC Circuit, Square-Wave Input; Analysis of RL Circuits: Series RL Circuit, Step Input; Intuitive Analysis, Propagation Delay and the Digital Abstraction, Definitions of Propagation Delays, Computing t_{pd} from the SRC MOSFET Model, State and State Variables, The Concept of State, Computer Analysis Using the State Equation, Zero-Input and Zero-State Response, Solution by Integrating Factors, Effect of Wire Inductance in Digital Circuits, Ramp Inputs and Linearity, Response of an RC Circuit to Short Pulses and the Impulse Response, Intuitive Method for the Impulse Response, Clock Signals and Clock Fanout, RC Response to Decaying Exponential, Series RL Circuit with Sine-Wave Input, Digital Memory, The Concept of Digital State, An Abstract Digital Memory Element, Design of the Digital Memory Element, A Static Memory Element.
Energy and Power in Digital Circuits: Power and Energy Relations for a Simple RC Circuit, Average Power in an RC Circuit and energy dissipation, Power Dissipation in Logic Gates, Static Power Dissipation, Total Power Dissipation, NMOS Logic, CMOS Logic, CMOS Logic Gate Design.

UNIT - IV

Transients in Second-Order Circuits: Undriven LC Circuit, Undriven, Series RLC Circuit, Under-Damped Dynamics, Over-Damped Dynamics, Critically-Damped Dynamics, Stored Energy in Transient, Series RLC Circuit, Undriven, Parallel RLC Circuit, Under-Damped Dynamics, Over-Damped Dynamics, Critically-Damped Dynamics, Driven, Series RLC Circuit, Step Response, Impulse Response, Driven, Parallel RLC Circuit, Step Response, Impulse Response, Intuitive Analysis of Second-Order Circuits, Two-Capacitor or Two-Inductor Circuits, State-Variable Method, State-Space Analysis, Numerical Solution, Higher-Order Circuits
Sinusoidal Steady State: Impedance and Frequency Response, Analysis Using Complex Exponential Drive, Homogeneous Solution, Particular Solution, Complete Solution, Sinusoidal Steady-State Response, The Boxes: Impedance and its examples.
Frequency Response: Magnitude and Phase versus Frequency, Frequency Response of Capacitors, Inductors, and Resistors; Intuitively Sketching the Frequency Response of RC and RL Circuits; The Bode Plot: Sketching the Frequency Response of General Functions;
Filters, Filter Design Example: Crossover Network, Decoupling Amplifier Stages, Time Domain versus Frequency Domain Analysis using Voltage-Divider Example, Frequency Domain Analysis,Time Domain Analysis, Comparing Time Domain and Frequency Domain Analyses, Power and Energy in an Impedance, Arbitrary Impedance, Pure Resistance, Pure Reactance, Power in an RC Circuit
Sinusoidal Steady State: Resonance, Parallel RLC, Sinusoidal Response; Homogeneous Solution, Particular Solution, Total Solution for the Parallel RLC Circuit, Frequency Response for Resonant Systems, The Resonant Region of the Frequency Response, Series RLC, The Bode Plot for Resonant Functions, Band-pass Filter, Low-pass Filter, High-pass Filter, Notch Filter, Stored Energy in a Resonant Circuit.

UNIT - V

The Operational Amplifier Abstraction: Historical Perspective, Device Properties of the Operational Amplifier, The Op Amp Model, Simple Op Amp Circuits, The Non-Inverting Op Amp, The Inverting Connection, Sensitivity, A Special Case: The Voltage Follower, An Additional Constraint: $v^+ - v^- \cong 0$, Input and Output Resistances, Output Resistance, Inverting Op Amp, Input Resistance, Inverting Connection, Input and Output R For Non-Inverting Op Amp, Generalization on Input Resistance, Op Amp Current Source, Adder, Subtracter, Op Amp RC Circuits,, Op Amp In-

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tegrator, Op Amp Differentiator, An RC Active Filter, The RC Active Filter Impedance Analysis, Sallen-Key Filter, Op Amp in Saturation, Op Amp Integrator in Saturation, Positive Feedback, RC Oscillator, Two-Ports.

Diodes, Semiconductor Diode Characteristics, Analysis of Diode Circuits, Method of Assumed States, Nonlinear Analysis with RL and RC, Peak Detector, Clamping Circuit, A Switched Power Supply using a Diode, Clipping Circuit, Exponentiation Circuit, Limiter, Full-Wave Diode Bridge, Zener-Diode Regulator, Diode Attenuator

Suggested Texts and References:

1. **Text Book:** Foundations of Analog and Digital Electronic Circuits. Agarwal, Anant, and Jeffrey H. Lang. San Mateo, CA: Morgan Kaufmann Publishers, Elsevier
2. "Electrononcs Principals and Applications" Tata McGraw-Hill, (Ninth Edition), Charles A. Schuler
3. "Measurements and Instrumentation Principles", Third Edition, by Alan S. Morris
4. "Electronic Devices and Circuit Theory" by R. L. Boylestad, L. Nashelsky, K. L.Kishore, Pearson
5. "Electronic Principles" by Malvino and Bates
6. "Electronic Circuit Analysis and Design" by Donald A. Neamen, Tata McGraw Hill
7. "Electronic Devices and Circuits" by David A. Bell
8. "Digital Principles and Applications" by Leach, Malvino and Saha
9. "Modern Digital Electronics", Tata McGraw-Hill (2003) by R.P. Jain
10. "Digital Design", Pearson Education Asia, (2007) by M. Morris Mano, Michael D. Ciletti
11. "Digital Fundamentals", Pearson Education Asia (1994) by Thomas L. Floyd

Learning Outcome
Integrated M.Sc. in Physics
Center for Basic Sciences
Pt. Ravishankar Shukla University, Raipur (C.G.)

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Integrated M.Sc. in Physics
Center for Basic Sciences
Pt. Ravishankar Shukla University, Raipur (C.G.)

OBJECTIVES :

The objective of Integrated M. Sc. in Physics is to create a pool of highly qualified talented and motivated young students with professional competence in physics with ability

- to embark on careers in front line research and development in physics.
- to take research challenges in the interdisciplinary nature of contemporary physics subjects (e. g. biophysics, medical physics, computational physics).
- to recognize and respond to the scientific demands relevant to need of the country.
- to contribute to the society with their skill and knowledge for uplifting the scientific temperament of the society.

Program Educational Objectives :

PE01: Development of scientific reasoning skills

Student should be able to find a way to comprehend and analyze a new physical process (not discussed in class) in real life by applying adequate sequence of reasoning, starting from fundamental principles of physics leading to come up with predictions or inference about the process.

PEO2: Development of organised knowledge of the major branches of Physics

Student should have knowledge of various branches of physics in enough depth and width to be able to recognise properties of real system by making connections/ links between concepts covered in different courses.

PEO3: Development of quantitative understanding of physical theories and problem solving abilities

Student should be well versed with use of appropriate mathematical tools and should be able to connect the different representations viz. Mathematical expressions, verbal descriptions, Graphs, diagrams. Student should be able to understand approximations used to arrive at the result and its implication on the ranges of validity.

PEO4: Development of familiarity with laboratory techniques and computational skills

Student should be able to perform laboratory exercises, document and analyze the observations, understand sources of error, and ultimately should be able to design an experiment in domain of physics. Student should have familiarity with basic programming techniques, numerical methods and statistical techniques.

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PEO5: Development of ability of communicating science to peers and to the society

Student should be able to communicate concisely and clearly about a subject through presentation or writing to various audience, including peers and general public.

PEO6: Development of ability to complete a guided research project

Student should have ability to do an effective literature search, apply adequate method to collect, document and process and analyze the data draw inferences and interpret the results obtain. Should have ability to write a research proposal and formal research paper.

Program Learning Outcomes :

- Student should acquire knowledge and problem-solving skills to pass National level CSIR/UGC NET and State level SET/SLET examination in Physical Science Subject during final year of the course .
- Student should have competence to get selected for Ph. D. Programs in reputed national and international research institutes/universities.
- Student should be able to approach eminent scientists and research institutes with a research proposals to carry out short term/ long term projects.
- Students should have conceptual clarity of the learned topics to be a potentially science teacher of high caliber

General Pattern of the Program

The course structure of five year Integrated-M.Sc. Physics is designed to start the journey so as to help the student to perform a journey from introduction of the subject in the first semester to an advanced level of understanding in the final semester and also give him/her glimpses of contemporary research in the stream of specialization and/or other interdisciplinary areas.

- The curriculum for the first two semesters (first year) is common to all students (10+2 PCM and PCB group) and consist of (i) Introductory theory courses in biology, chemistry, mathematics and physics, (ii) Laboratory courses, and (iii) courses in communication skills, computer basics as well as electronics.
- At the beginning of the second year (third semester), a student will opt for specialization in one of the streams (Biology, Chemistry, Mathematics or Physics) according to their choice.
- In the second and third years of study, the students are taught courses not only in the specialised discipline, but often courses from other science disciplines as well, as recommended for an integrated understanding of the subject matter.
- The courses in fourth and fifth years of the integrated M.Sc. Programmer are more advanced in nature and are mainly from the respective disciplines, although there are some interdisciplinary courses.

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- The Center focuses on imparting a complete education and prescribes some compulsory courses which belong to humanities, social sciences, technical communication, history of science, environmental and energy sciences, etc.
- In order to expose the young minds to research early in their career, the students are offered projects from 4th year onward. Thus, in 7th semester they are exposed to supervised learning of a research topic, followed by a mini research project in 8th semester. The 9th semester entails a dissertation, where the students need to go outside of the CBS to carry out a full semester external project.
- The students are thus encouraged to take up summer projects and visit reputed national, international laboratories and universities, so as to broaden their vision and widen their horizon.
- Students also get an opportunity to learn from and interact with eminent scientists from India and abroad who are invited to the Center at regular intervals to deliver colloquia and seminars.

PAPER WISE LEARNING OUTCOME :

SEMESTER- I

P101: Introductory Physics-I (For all streams)

This is common paper for 10+2 biology and mathematics background students. A portion of the content significantly overlaps with 10+2 , the approach taken in delivery is meant to be inclined towards developing the thought process that leads to the conclusions that are being familiarized. The course aims to consolidate the knowledge acquired at +2 level by the student and create deep interest to understand laws of nature by means of developing understanding of physics. The scope of content covered includes -

- A relation of physics with other sciences. Review of conservation of energy and characteristics of fundamental forces.
- Development of an understanding of oscillations with particular emphasis on simple harmonic motion.
- Understanding of phenomenon of resonance and able to understand resonance observed in the nature
- A review of Thermodynamics, as a Macroscopic study of complex systems, mostly in the context of ideal gases.
- A review of microscopic analysis of ideal gases using the kinetic theory of gases.

PL101: Physics Laboratory – I

After successfully completing the laboratory exercises

- Student should have working knowledge of Plots (normal, semi-log, log-log).
- Student should have understanding of uncertainty / error in measurements and uncertainty / error analysis.
- Student should have understanding of concepts of standards and calibration.

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SEMESTER - II

P201: Introductory Physics-II (For all streams)

The course introduces the students how mathematical, and graphical tools can be used to simplify the problems and make it possible to visualize the physical phenomena for better understanding. After successful completion student will learn

- how to apply Gauss's law in variety of problems for finding value of electrostatics field
- magnatostatics, and plane electromagnetic waves
- Interference of light using wave theory of light
- Basic concepts geometrical optics
- How human eye detect light and perceive colour

PL201: Physics Laboratory – II

This course covers a theoretical understanding of functionality of electronic components in circuitry and also develops the thought process for instrumentation. In this course, students will gain understanding of

- Basic circuit analysis and network theorems
- foundational electronic components like diodes and transistors.
- More complex electronic components and a variety of applications of the same
- Introductory level digital electronics that includes fundamental memory devices
- Introductory instrumentation which includes and understanding of concepts like sensing and transduction.

G201- Electronics & Instrumentation

This course covers a theoretical understanding of functionality of electronic components in circuitry and also develops the thought process for instrumentation. In this course, students will gain understanding of

- The basic electronics principles and abstractions on which the design of electronic systems is based. These include lumped circuit models, digital circuits, and operational amplifiers.
- Using the abstractions to analyze and design simple electronic circuits.
- Employing Boolean algebra to describe the function of logic circuits.
- Designing circuits which represent digital logic expressions. Specifically, design a gate-level digital circuit to implement a given Boolean function.
- Basic principals behind measuring instruments

GL201 Electronics laboratory

Student will do experiments to learn

- Network theorems
- Diode characteristics in forward and reverse biasing mode.
- How capacitors charges and discharges.
- Characteristics of PNP and NPN transistor.
- To find specific resistance using Wheatstone bridge.

SEMESTER - III

P301: Mathematical Physics – I

After successfully completing this course

- The students will be able to understand and apply the mathematical skills to solve
- quantitative problems in the study of physics.
- Will enable students to apply integral transform to solve mathematical problems of
- interest in physics.
- he students will be able to use Fourier transforms as an aid for analyzing experimental data.
- The students should be able to formulate and express a physical law in terms of tensors, and simplify it by use of coordinate transforms.

P302: Classical Mechanics – I

This course would serve as a foundation in ensuring an appropriate level of understanding of the statics and dynamics necessary for other advanced subjects of physics. Student will gain understanding of

- Fundamental concepts of forces, energy, potentials, linear and angular momentum
- A rigorous exercise in Newtonian Mechanics including that of its applications in Rigid bodies
- Frames of reference
- Statics and Dynamics of Einstein's special relativity
- Introduction to four vectors and concept of spacetime

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P303: Electromagnetism

After successfully completing this course

- Student should be able to explain and solve advanced problems based on classical electrodynamics using Maxwell's equation.
- The students will be able to analyze s radiation systems in which the electric dipole, magnetic dipole or electric quadruple dominate.
- The students will have an understanding of the covariant formulation of electrodynamics and the concept of retarded time for charges undergoing acceleration.

P304: Waves and Oscillations

After completing this course student should

- be able to recognize and use a mathematical oscillator equation and wave equation, and derive these equations for certain systems, point out the limitations and be able to refer to very different solutions of identical oscillator equations due to different initial and boundary conditions.
- explain several phenomena we can observe in everyday life that can be explained as wave phenomena, and identify basic principles,
- Understand physical characteristics of SHM and obtaining solution of the oscillator using differential equations
- explain how several waves or parts of waves interact, and be able to calculate and analyze diffraction and interference phenomena, and explain the conditions required for such phenomena to appear.
- describe and calculate what happens when waves move from one medium to another, and be able to explain dispersion and group and phase velocity.
- use geometric optics to describe and explain optical instruments, and by simple measurements estimate what strength glasses a person needs
- use both analytical mathematics and numerical methods to explore the subjects mentioned above. In particular you should be able to analyze experimental oscillator or wave phenomena, such as sound, using suitable methods.

H302 : History and Philosophy of Science (All streams)

After successful completion of this course students should learn

- History of World Science up to the Scientific Revolution.
- History of Ancient Indian Science.
- Philosophy of Science and distinction between science and pseudo science.
- Great Scientific Experiments (though group activity)

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PL301: Physics Laboratory – III

After successful completion of this course students should have the procedural and conceptual understanding of the following experiments

- Frequency response of R-C circuit (concept of cut-off freq and filter).
- frequency response of LC circuit.
- concepts of phase difference between voltage and current in these circuits.
- phase factor for appliances using AC mains supply.
- R-L-C (series / parallel) resonance.
- transient response in RL- C series circuit.
- study of Newton's rings.
- determination of the charge of an electron by Millikan's oil drop experiment.

GL301: Applied Electronics Laboratory

After completing the laboratory exercises student will learn

- Working of Logic gates
- half and Full Adder circuits
- De-Morgan's Theorem
- Edge triggered D-Flip Flop
- working of rectifier circuits
- working of filter circuits
- regulated power supply

SEMESTER - IV

P401: Mathematical Physics – II

After successful completion of this course students should have understanding about

- Partial differential equations in curvilinear coordinates
- In-homogeneous equations, Green's functions in 1,2 and 3-dimensions
- Tensors calculus
- Various integral equations
- subgroups, normal subgroup, classes and cosets;

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P402: Quantum Mechanics – I

After successfully completing the course, student will :

- Understand inadequacy of classical mechanics and need of a new mechanics
- Understand and explain the differences between classical and quantum mechanics.
- Under stand quantization of physical variables, wave function and its interpretation
- Under the postulates of quantum mechanics and apply it to find wave function for simple problems
- Understand 1-D scattering in quantum mechanics
- acquire adequate and essential background knowledge to study Quantum Mechanics -II (P501)

PCB 401: Physical and Chemical Kinetics

Student will gain understanding of

- Basic concepts of chemical kinetics, theories, fundamental terms, complex reactions and derivations.
- Reactions in solutions and their kinetics too.
- Various techniques for kinetic measurements (for fast reactions) are also described (like temperature and pressure jump methods, flash photolysis).
- Catalysis and surface reactions are also discussed.

G401: Statistical Techniques and Applications

After successful completion of this course students will learn

- Purpose of studying Statistics
- Different types of probability distributions
- Monte Carlo techniques
- Deconvolution methods
- Different types of statistical tests

PL401: Physics Laboratory – IV

This course is meant as an exercise in a basic understanding and application of ExpEyes kit for variety of physics and electronics experiments. After successful completion of this course students will be able to setup and perform experiments of

- Tensors calculus
- Electronics: including rectifier circuits, diode characteristics, transistor characteristics
- Electrical circuits: including combination of L,C,R components in series and parallel
- Mechanics: including gravity pendulum, driven pendulum distance measurement by echo
- Sound: including velocity of sound in Air, Sound Beats etc.

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GL401: Computational Laboratory and Numerical Methods

After successful completion of this course students will learn

- The nature of computational physics
- Basic tools for numerical analysis in science
- Writing programs for problems of Matrix Algebra
- Writing programs for solving Differential Equations
- Writing programs for solving problem related to Fourier analysis and nonlinear systems

SEMESTER - V

P501: Quantum Mechanics – II

after successful completion of this course

- Student will be able to solve eigen value problems for simple cases like particle in a box, harmonic oscillator
- Student will learn abstract vector space formulation of quantum mechanics
- Student will learn quantum mechanical treatment of particle with central potential
- Student will learn stationary perturbation theory for non – degenerate and degenerate case
- Student will learn variational method in quantum mechanics and its application
- Student will acquire essential knowledge to study Quantum Mechanics -III (P702) course

P502: Classical mechanics – II

This is a second course in Classical mechanics will help students gain an understanding of

- Lagrangian and Hamiltonian approach to dynamics
- Canonical Transformations
- Small oscillations in simple and coupled systems
- Brief understanding of application of this approach to continuous media

P503: Atomic and Molecular Physics

After successful completion of this course

- Student should learn Atomic Physics with problem solving approach towards spectroscopy.
- Student should have an understanding of the static properties of nuclei, nuclear force and nuclear models.
- students should have an understanding of the structure of the nucleus, radioactive

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- decay, nuclear reactions and the interaction of nuclear radiation with matter.
- Students will have an understanding of quantum behavior of atoms in external electric and magnetic fields.

PM501: Numerical Analysis

PL501: Physics Laboratory - V

In this course student will go through rigorous customization and python programming-based implementation of Expeyes. And make his own program and experimental arrangement to study :

- students should have an understanding of the structure of the nucleus, radioactive
- decay, nuclear reactions and the interaction of nuclear radiation with matter.
- Variable mass pendulum
- Coupled pendulum
- Study of EMI
- Study of characteristics of solar cell
- Velocity and acceleration measurement

PML501: Numerical Methods Laboratory

SEMESTER - VI

P601: Electrodynamics

In this course students will develop understanding of

- Gauge theory, diff erent types of radiating systems, antenna, solution of scalar wave equation.
- Multipole expansion of electromagnetic fields
- Scattering and diffraction problems
- Covariant formulation of electrodynamics
- Field produced by moving charge

P602: Statistical Mechanics - I

This course introduces the phenomenon of dealing with physical properties of a complex system via a statistical microscopic analysis. Statistical Mechanics has limitless applications in understanding a variety of physical systems. Student will gain understanding of

- Probability distribution and ensemble theory
- Differences and implications of dealing with a variety of systems under classical and quantum mechanical framework

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- The natural differences and implications of Bosonic and Fermionic systems.
- Applications of this concept in explaining properties like paramagnetism and specific heat of materials.

P602 Computational Physics - A (only for SEMESTER-IV students of session 2021-22)

In this course both quantum and classical computational tools will be introduced. The course aims to give the students competence in the methods and techniques of calculations using computers. At the end of the course the student is expected to have

- a hands on experience in modeling.
- understanding of algorithm development.
- understanding of implementation and calculation of physical quantities of relevance in interacting many body problems in physics.

P603: Condensed Matter Physics – I

In this course, which is a primarily a study of ordered crystals, Student will gain understanding of

- Crystallography
- Lattice vibrations and properties of solids
- Free electron model and electronic specific heat
- Understanding semiconductors, magnetic properties and superconductivity

P604: Lasers

After successful completion of this course

- Student should understand operational principles and construction of lasers
- Student should understand technological issues behind laser construction
- Student should understand optical components that can be used to tailor the properties of the laser
- Student should understand be able to relate the laser operation principles to atom and molecular physics, solid state physics, quantum mechanics and physical optics.

H 601 Ethics of Science and IPR

After successful completion of this course student will learn

- Role and importance of ethics in science.
- About what is plagiarism, and softwares for plagiarism detection
- Types of Intellectual property
- Definition of patent, patent able and non patentable inventions
- Evolution of institution like, GATT and WTO and IPR provisions under TRIPS

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PL601: Physics Laboratory – VI

After successful completion of this course student should have procedural and conceptual understanding of the following experiments:

- determination of specific charge (e/m) of electron.
- Study of Faraday rotation and determination of Verdit's constant in a glass material.
- Study of quantum mechanics through acoustic analogue (four sessions).
- Fourier analysis / synthesis – use of simulation.
- Study of characteristics of a coaxial cable and determination of speed of electromagnetic waves in the coaxial cable.
- Investigation of chaos in a spring based coupled oscillator system.

SEMESTER - VII

P701- Astronomy and Astrophysics - I

This is an introductory course for astronomy and astrophysics it will develop foundations of basic concepts of students to take more advance course in astronomy and astrophysics. The student will learn

- Concepts of distance scale of the universe, measurement of brightness of the astronomical objects
- Physics behind the observed spectra of the star. Stellar evolution of the stars using H-R diagram
- Working of telescope and requirement of different telescope for observation in different wavelengths
- Basic properties of Sun as a star
- Astronomical coordinate systems
- Database of the astronomical objects and conversion of nomenclature of the stars
- Essential background to study Astronomy and Astrophysics-II (P801)

P702: Quantum Mechanics – III

After successful completion of this course

- Student should able to understand deeper concepts of quantum mechanics and should comprehend advanced topics like The EPR paradox, quantum entanglement and decoherence
- Student should understand Symmetry in quantum mechanics.
- be able to understand development of relativistic quantum mechanics.
- Student should have an understanding of Dirac's equation in external electromagnet field.
- be able to solve relativistic one-body problems for spin 0 and $\frac{1}{2}$ particles.
- student will learn the solutions of Dirac's equation and its interpretation.
- Student will have adequate background knowledge to take a course on Quantum Field Theory

P703: Statistical Mechanics – II

In this course students will develop understanding of

- Transport phenomena and equations governing the transport in the presence and absence of collisions, random walk problem
- Concept of diffusion and equations governing diffusion
- phenomena of phase transition, types of phase transition and Landau theory of second order phase transition
- Critical phenomena, critical exponent, exponent inequalities

P704: Nuclear Physics-I

Understanding the properties of Nucleus is integral to various physical phenomenon. This course develops an understanding of

- The various properties of nucleus
- Nuclear stability and factors affecting binding energy of nucleus
- Nuclear structure under different models
- Nuclear forces and scattering
- Nuclear decay
- Nuclear interactions and fission/fusion process

P704 Computational Physics - B (only for SEMESTER-VI students of session 2021-22)

In this course both quantum and classical computational tools will be introduced. The course aims to give the students competence in the methods and techniques of calculations using computers. At the end of the course the student is expected to have

- a hands on experience in modeling.
- understanding of algorithm development.
- understanding of implementation and calculation of physical quantities of relevance in interacting many body problems in physics.

PL701: Advanced Physics Laboratory – I

After successful completion of this course student should have procedural and conceptual understanding of the following experiments

- Spectral features of photoelectric absorption and Compton scattering with scintillation detectors
- Growth of metallic thin films by physical vapor deposition techniques
- operation of a closed cycle cryostat, low temperature thermometers
- using of a dual phase lock-in amplifier. Measurement of the superconducting transition temperature of a superconducting thin film using a mutual inductance technique

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PPr701: Reading Project

Student learn to carry out supervised leaning of a research topic, write the report on the topic on own words and make a presentation of the learned topic.

SEMESTER - VIII

P801: Astronomy and Astrophysics

After successful completion of this course student should have understanding of

- Stellar physics: the equations governing the structure of stars
- various models of stellar structure with linear & quadratic density profiles.
- Stellar evolution from birth of stars to its possible end states
- structure of Milkyway and necessity of multiwavelength observations in astronomy
- active galactic nucleus
- introductory cosmology and models of the universe

P802: Fluid Mechanics

In this course students will develop understanding of

- Stellar physics: the equations governing the structure of stars
- various models of stellar structure with linear & quadratic density profiles.
- Concept of hydrodynamics, and description of hydrodynamical systems, flow fields,
- and basic equations governing conservation of mass, momentum & energy in hydrodynamical systems
- Equation governing viscous flow, concept of shear and bulk flow viscosity, boundary layers, potential flow, , water waves and lubrication theory of flow
- Tensor representation of viral theorem, flow in magnetic fluids, Generalized Ohm's law & Ambipolar diffusion, Magneto-gravity-acoustic modes
- Stability problem in classical hydrodynamic and hydromagnetic specially Rayleigh-Taylor and Kelvin-Helmholtz instabilities. Jeans' gravitational instability; Benard convection. Parker instability and magnetic buoyancy. Thermal instability.
- Concept of accretion flows and accretion disks, shock and blast waves, hydrodynamics in supernova and blood flow in human heart

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P803: Nuclear and Particle Physics

In this course students will develop understanding of

- Stellar physics: the equations governing the structure of stars
- Concept of phase shift, partial wave decomposition, cross section, scattering, optical potential
- Derivation of the resonance cross section, description of cross section, barrier penetration, resonance scattering and compound nucleus model
- Direct reaction and application to various method, high energy scattering and evolution of scattering cross section, heavy ion scattering and physics with radioactive ion beams. Single particle shell model, gas models, deformation in nuclear shape, superheavy nuclei, and spectroscopy of drip-line model
- Basic classification of particles, types of fundamental forces, relativistic kinematics of particle reactions, conservation and symmetries, conservation laws for different quantum numbers, symmetry breaking and generating of masses, families of particles, gauge theory, detection of particles (quarks and gluons)

P804: Condensed Matter Physics – II

The objective of this Advanced course in condensed matter physics is to

- Understand the Phenomenon that governs and explains superconductivity
- Look into various approaches that explain different kinds of magnetic phenomenon
- Introduce density functional theory and a view into some peculiar physical phenomenon in solids

PL801: Advanced Physics Laboratory – II

After successful completion of this course student should have learned methodology and conceptual understanding of the following experiments

- Study of orbit of a visual binary star Kruger 60. Construct an orbit diagram in order to verify that this binary system follows Kepler's law of motion
- Determine the rotational velocity of Saturn. Study the differential motion of ring particles to check that ring particles follow the Keplerian orbit, hence determine the mass of Saturn.
- Study of proper motion of 61 Cygni.
- Determine the period of Pulsars from their pulse profile in different radio frequencies. Find the dispersion by measuring delay in arrival time of pulses at two frequency bands and hence determine distances of the Pulsars.
- Study of Quasar 3C273 and determine its red-shift, recessional velocity, distance, apparent magnitude, absolute magnitude and size of the emitting region. Find that it is very compact yet very luminous object.
- Study of Hubble's law and expansion of the Universe using the spectra of different galaxy cluster fields. Determine the Hubble's constant and age of the Universe.

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- Perform photoelectric photometry (in B and V filters) of Pleiades star cluster in order to construct HR Diagram and determine the distance using Main Sequence Fit method.
- Study of light curves of Cepheid Variable stars and determine the distance of Small Magellanic Cloud (SMC) using Cepheid Variable's Period Luminosity Relation.

PPr801: Project

Student will learn to carryout in house supervised research project, submit a report and make a formal presentation of the project.

SEMESTER - IX

PPr901: Project

Student will learn to carryout full semester project outside of the institute with external supervisor, submit a thesis dissertation and make formal presentation of research project.

SEMESTER - X

PE - 1: Quantum Field Theory

After successful completion of this course student should have understanding of

- reasons for the failure of relativistic quantum mechanics, such as the causality problem, and the need for quantum field theory
- the origin of particles and forces
- Analysis of the statistical distributions of identical particles and the repulsive/attractive nature of the forces as a function of spins
- Application of the Feynman rules to calculate probabilities for basic processes with particles (decay and scattering)
- Obtaining classical and/or non-relativistic limits of fully quantum and relativistic models, and identify the relativistic origin of effects such as the spin-orbit interaction
- Useing effective field theory techniques to develop models at large scales
- Describing qualitatively effects such as superconductivity, superfluidity, and ferromagnetism using the concepts of gauge invariance, Goldstone and Higgs mechanism, and spontaneous symmetry breaking.

PE - 2: General Relativity and Cosmology

The objective of this course is to make the student develop an understanding of

- The concept of spacetime in the context of Einstein's Relativity
- Gravity as curving of spacetime

- Results like precession of orbits and black holes
- Cosmology and expansion of the universe
- Gravitational and cosmological redshift

PE - 3: Experimental Techniques

After successful completion of this course student should have understanding of

- Vacuum technology
- Optical systems experimental techniques
- Detectors and its properties used for the experiments
- Particle detectors and radioactive Decay
- Basic electronics of the detectors

PE - 4: CCD Imaging and Spectroscopy

After successful completion of this course student should have understanding of

- Importance of CCD, manufacturing and operations
- Characterization of charge-coupled devices
- Method of CCD imaging, Photometry and astrometry.
- Working principle of CCD Spectrograph and astronomical spectroscopy
- CCDs used in space and at short wavelengths

PE - 5: Biophysics

After successful completion of this course student should have understanding of

- Mathematical Methods in Biophysics
- Quantum Mechanics Basic to Biophysical Methods
- Computational Modeling of Receptor–Ligand Binding and Cellular Signaling Processes
- Stochastic Simulation Algorithms used in biophysics
- Fluorescence Spectroscopy: Fundamental Process of Fluorescence
- Electrophysiological Measurements of Membrane Proteins

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PE - 6: Particle Physics

After studying this course, student should be able to

- recognise and name the six flavors of lepton and the six flavors of quark.
- understand that all leptons and quarks have corresponding antiparticles
- appreciate that quarks and antiquarks combine to form baryons, antibaryons and mesons.
- write balanced strong interactions, understanding the role of gluons
- write balanced weak interactions, understanding the role of W and Z bosons

PE - 7: Nonlinear Dynamics and Chaos

In this course students will develop understanding of

- Dynamical system and their classification, phase portrait representation of dynamical system.
- 1-D map, eigen value equation and concepts and properties of eigen values.
- Stability analysis of dynamical systems, concept of fixed point, limit cycle, manifold.
- Linearization of fields, classification of fixed point, manifold theorems.
- Concepts of neighborhood, bifurcations, classification of bifurcations, bifurcations diagram
- Introduction of chaos, fractals, Hamiltonian dynamics

PE - 8: Reactor Physics and Radiation Science

After successful completion of this course student should have understanding of

- Fission process
- Interaction of Neutrons with Matter
- Concept of microscopic cross section
- Diffusion of neutrons
- Chain Reaction
- Slowing down process
- Heterogeneous reactors
- Reactor kinetics
- Neutron Poisons
- Reactivity coefficients

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PE - 9: Accelerator Physics and Applications

After this course

- student will understand how different particle accelerators are designed (linear accelerators, cyclotrons and synchrotrons), as well as the possibilities and limitations of the different accelerator types
- student will master simple calculations and methods for numerical simulations describing how a particle beam is accelerated, focused and measured
- student will have knowledge of machines for high-energy physics, including studies for future linear and circular colliders
- student will have knowledge about the accelerator science research frontier, including laser- and plasma wakefield acceleration
- student will have knowledge about the most important applications of particle accelerators to particle physics, material science and medical technology
- student will master theory and techniques for numerical simulations of charged particle beams

PE - 10: Computational Physics - C

In this course both quantum and classical computational tools will be introduced. The course aims to give the students competence in the methods and techniques of calculations using computers. At the end of the course the student is expected to have

- a hands on experience in modeling.
- understanding of algorithm development.
- understanding of implementation and calculation of physical quantities of relevance in interacting many body problems in physics.

PE - 11: Glimpses of Contemporary Sciences

After successful completion of this course. Students will have understanding of

- how physics can be used to increase understanding of various life systems in nature
- modeling of thermodynamics and human population, Falling leaves, Smoke ring.
- study done in filed of Astrochemistry and Astrobiology
- process of bringing atoms to rest, and Laser tweez- ers.

PE - 12: Earth Science and Energy & Environmental Sciences

After successful completion of this course student will have exposure of

- Theories of origin of earth
- Structure of different layers of earth, plate tectonics and geodynamics and the role of mantle plumes in sustaining these processes.

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- Electrical and magnetic properties of the different layers in the earth
- Geodynamo and the internal magnetic field of the earth.
- Natural calamities, hazards, and effects of human activity.
- Concept of sustainability, individual and social, and local and global actions for a sustainable future.
- Energy Sources - evolution of energy sources with time.
- Nuclear energy power production in India

PE - 13: Circuits and Electronics

This course is designed to develop students concept of basic electronics principles. After successful completion fo the course students will

- Understand the concepts of employing simple models to represent non-linear and active elements-such as the MOSFET-in circuits.
- Build circuits and take measurements of circuit variables using tools such as oscilloscopes, multimeters, and signal generators. Compare the measurements with the behavior predicted by mathematics models and explain the discrepancies.
- Understand the relationship between the mathematical representation of circuit behavior and corresponding real-life effects.
- Appreciate the practical significance of the systems developed in the course.
- Determine in the laboratory the time-domain and frequency-domain behavior of an RLC circuit. Use operational amplifier models in circuits which employ negative feedback.
- Use complex impedances to determine the frequency response of circuits.
- Determine the power dissipation in digital gates and employ CMOS technology to reduce static power losses.
- Predict how a given circuit will affect an audio signal in the laboratory given the frequency response of the circuit.
- Design, build and test an audio playback system which includes both analog and digital components.

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Center for Basic Sciences
Pt. Ravishankar Shukla Univesrity, Raipur(C.G.)

Program: Five Year M.Sc. Integrated (Physics Stream)

Following is the list and description of the modifications in the course structure/papers/units of the papers of Five Year M.Sc. Integrated (Physics Stream) Course :

List of papers with modification in its content

S. N.	Paper with code / Semester	Modified paper with code/ Semester	Justification	Remark
1.	H302 : History and Philosophy of Science (All streams) (Semester III) **UNIT - I** History of World Science up to the Scientific Revolution: Introduction about Stone Age, beginning of agriculture, urban civilization and science. Science in Sumeria, Babylonia and Egypt. Natural philosophy of pre-Socratic Greece. Natural philosophy in Athens. Greek science in the Alexandrian period. Rome and decline of Ancient European science. Science and technology in China. Science and technology in the Muslim world. Technology and the craft tradition in medieval Europe. The scholarly tradition during the middle ages **UNIT - II** Renaissance, the Copernican system of the world. Gilbert, Bacon and the experimental method. Galileo and the science of mechanics. Descartes – the mathematical method and the mechanical philosophy. The Protestant reformation and the scientific revolution. Newton –the theory of universal gravitation and optics. Alchemy and iatrochemistry. Medicine, theory of circulation of blood. Growth and characteristics of the scientific revolution. **UNIT - III** History of Ancient Indian Science: Indian civilization from pre-historic times to the Indus Valley Civilization. Ancient Indian mathematics and astronomy. Ancient Indian medicine and biology. Chemistry, metallurgy and technology in general in ancient India. Strengths, weaknesses and	H302 : History and Philosophy of Science (All streams) (Semester III) **UNIT - I** History of World Science up to the Scientific Revolution: Introduction to stone age, fire, agriculture, the ceramic breakthrough, The technology of metals, discovery and development of glass, writing and scientific record, measurement-essential to all science. urban civilization, and science. Science in Sumeria, Babylonia, and Egypt. Natural philosophy of pre-Socratic Greece.Science and technology in China and the Muslim world. Renaissance and the Copernican system. Galileo and the science of mechanics. Descartes and the mathematical method. Newton's theory of universal gravitation and optics. Growth and characteristics of the scientific revolution. **UNIT - II** History of Ancient Indian Science: Indian civilization from pre-historic times to the Indus Valley Civilization. Ancient Indian mathematics and astronomy. Ancient Indian medicine and biology. Chemistry, metallurgy and technology in general in ancient India. Strengths, weaknesses and potentialities of ancient Indian science. **UNIT - III** Introduction to Philosophy of Science: What is science?, Scientific Methodology, Falsificationism, Scientific reasoning; scientific temperament; Explanation in science; Realism and instrumentalism; Scientific change and scientific revolutions.	The syllabus now explicitly addresses the rationality, objectivity, and values in science, promoting critical thinking and ethical considerations in scientific practice. Additionally, the study and presentation of pseudoscience examples by students encourage them to discern between scientific and non-scientific approaches. he inclusion of Eratosthenes' Experiment and group-wise study and presentations of historically significant experiments fosters active learning and engagement. These activities allow students to experience the scientific method	

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	poten-tialities of ancient Indian science. **UNIT - IV** Introduction to Philosophy of Science: What is science? Scientific reasoning; Explanation in science; Realism and instrumentalism; Scientific change and scientific revolutions. **UNIT - V** Great Scientific Experiments: Group wise study and presentations by students of historically significant experiments in science.	**UNIT - IV** Rationality, Objectivity, and Values in Science Science and Pseudo-Science, demarcation criteria, group wise study and presentation of Pseudoscience examples by students **UNIT - V** Eratosthenes Experiment, Great Scientific Experiments: Group wise study and presentations by students of historically significant experiments in science.	firsthand and appreciate the importance of experimental validation in scientific discoveries.	

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