DEPARTMENT OF PHYSICS

PONDICHERRY UNIVERSITY

CURRICULUM FOR

4-year BSc (Physics Honours)

Under

NEP 2020 Regulations

(For students admitted from the academic year 2024-25)

JANUARY 2024

ELIGIBILITY FOR ADMISSION

- Higher Secondary (12th Grade) Certificate of Central / State Board or equivalent in the Republic of India, with a subject combination of Mathematics, Physics, and Chemistry, and should have secured a minimum of 55% of marks in aggregate.

DURATION OF THE PROGRAM

- The BSc (Physics Honours) shall be of four years duration organized on the semester pattern with two semesters in a year.
- Exit options are available as per NEP 2020 regulations (see next page).
- Students may be permitted to take a break from their studies, and such students may be allowed to re-enter the degree program within three years and complete the program within the stipulated maximum of seven years.

MEDIUM OF INSTRUCTION

- The medium of instruction shall be English, except for language courses.

Eligibility to take UG research Project in the 4th year

Students who secure a minimum CGPA of 7.50 in the first six semesters and have cleared arrears (if any) are eligible to undertake a UG research project work in the fourth year. Others shall take coursework instead of the project work.

EXIT OPTIONS

AND

CREDITS REQUIREMENT

At the end of the	*Minimum Credits Required*	*Exit Option*
1st year	42 + 4*	Certificate in Physics.
2nd year	87 + 4**	Diploma in Physics.
3rd year	134	BSc (Physics) with Mathematics and Chemistry as Minor subjects.
4th year	181 (without Project)	BSc (Honors) in Physics with Mathematics and Chemistry as Minor subjects
	181 (with Project)	BSc (Honors with Research) in Physics with Mathematics and Chemistry as Minor subjects

* In addition, 4 credits of vocational courses are to be done during the summer vacation.
** In addition, 4 credits of vocational / internship course to be done in summer vacation.

ABBREVIATIONS

MAJ - Major	SEC - Skill Enhancement Course
MIN - Minor*	VAC - Value Added Course
MDC - Multi-Disciplinary Course	COM - Community Engagement
MIL - Modern Indian Language	INT - Internship (Major)
AEC - Ability Enhancement Course	PRO - Project Work

* Minor is inclusive of vocational / practical training, as per NEP 2020 regulations.

CREDITS / TUTORIALS / WORKLOAD

- A four-credit course means 4 hours of classroom lecture per week. A 4-credit theory course in a semester means 60 hours of classroom lecture.
- A 3-credit theory course in a semester means 45 hours of classroom lecture.
- One tutorial means one hour of tutorial session per week. Tutorial means helping the students solve numerical and analytical problems.
- For example, the PHYS 1110 (Mechanics) course is four credits plus one tutorial. The course teacher will have a 5-hour per week workload.
- Thirty hours of laboratory coursework means 15 hours of faculty workload.

DISTRIBUTION OF SUBJECTS AND CREDITS

Type of Course	*Credits*	*How many courses in the respective semester?*								*No. of Courses*	*Credits*
		I	II	III	IV	V	VI	VII	VIII		
MAJ	4	1	1	2	2	3	3	5	3	20	80
MIN	4	1	1	1	2	2*	2*	0	0	9	36
MDC	3	1	1	1	0	0	0	0	0	3	9
AEC	3	1	0	1	0	0	0	0	0	2	6
MIL	3	0	1	0	1	0	0	0	0	2	6
SEC	3	1	1	1	1	0	1	1	0	6	18
VAC	2	2	2	0	0	0	0	0	0	4	8
INT	4	0	0	0	0	1	0	0	0	1	4
COM	2	0	0	0	1	0	0	0	0	1	2
PRO #	12	0	0	0	0	0	0	0	1	1	12
	No. of Courses	7	7	6	7	6	6	6	4	49	
	Total Credits at the end of 4th year										181

* Minor has vocational / practical training.

Students not doing a project shall take coursework for 12 credits (3 papers each 4 credits).

PART – I

SKILL ENHANCEMENT COURSES

OFFERED BY THE PHYSICS DEPARTMENT

(for Physics Department Students)

Offered in Semester	*Course Code*	*Credits*	*Title of the Course*
1	PHYS – 110	3	Physics Laboratory – I
2	PHYS – 120	3	Physics Laboratory – II
3	PHYS – 210	3	Physics Laboratory – III
4	PHYS – 220	3	Physics Laboratory – IV
5	---	---	--- Nil ---
6	PHYS – 320	3	Physics Laboratory – V
7	PHYS – 410	3	Advanced Physics Laboratory

PART – II

MAJOR PAPERS

OFFERED BY THE PHYSICS DEPARTMENT

(for Physics Majoring Students)

S. No	*Offered in Semester*	*Course Code*	*Credits / Tutorial*	*Title of the Course*
1	1	PHYS – 111	4 + 1	Mechanics
2	2	PHYS – 121	4 + 1	Classical Thermodynamics
3	3	PHYS – 211	4 + 1	Acoustics and Oscillations
4	3	PHYS – 212	4 + 1	Electric Circuits Theory
5	4	PHYS – 221	4 + 1	Classical Optics
6	4	PHYS – 222	4 + 1	Analog and Digital Electronics
7	5	PHYS – 311	4 + 1	Modern Optics
8	5	PHYS – 312	4 + 1	Elements of Electromagnetics
9	5	PHYS – 313	4 + 1	Modern Physics
10	6	PHYS – 321	4 + 1	Atomic Spectra
11	6	PHYS – 322	4 + 1	Materials Science
12	6	PHYS – 323	4 + 1	Elements of Nuclear Physics
13	7	PHYS – 411	4 + 1	Mathematical Physics – I
14	7	PHYS – 412	4 + 1	Classical Mechanics
15	7	PHYS – 413	4 + 1	Quantum Mechanics – I
16	7	PHYS – 414	4 + 1	Electronic Devices and Circuits
17	7	PHYS – 415	4 + 1	Solid State Physics-I
18	8	PHYS – 421	4 + 1	Statistical Physics – I
19	8	PHYS – 422	4 + 1	Classical Electrodynamics
20	8	PHYS – 423	4 + 1	Atomic and Molecular Physics
21*	8	PHYS – 424	4 + 1	Mathematical Physics – II
22*	8	PHYS – 425	4 + 1	Solid State Physics – II
23*	8	PHYS – 426	4 + 1	Nonlinear Optics

* Students not undertaking a project will do these three course work (in lieu of the Project).

PART – III

MINOR COURSES

OFFERED BY THE PHYSICS DEPARTMENT

(for Mathematics / Chemistry / other Science Students)

(1) These courses are meant for students from mathematics, chemistry, biology, geology, computer science, and other science departments.

(2) The number of students may be restricted depending on the available classroom or laboratory facilities.

(3) A minimum of 10 students should register to offer the minor papers.

Offered in	*Course Code*	*Credits / Tutorial*	*Title of the Course*	*Pre-Requisite*
Odd	PHYS – 117	4 + 1	Concepts in Mechanics	HSC Maths
Even	PHYS – 127	4 + 1	Concepts in Thermodynamics	PHYS 117
Odd	PHYS – 217	4 + 1	Minor Physics Laboratory - I	PHYS 127
Even	PHYS – 227	4 + 1	Minor Physics Laboratory - II	PHYS 217
Odd	PHYS – 317	4 + 1	Minor Physics Laboratory - III	PHYS 227
Even	PHYS – 327	4 + 1	Concepts in Electromagnetism	PHYS 127
Odd	PHYS – 417	4 + 1	Concepts in Materials Science	PHYS 327
Even	PHYS – 427	4 + 1	Concepts in Plasma Physics	PHYS 327

PART – IV

MULTI-DISCIPLINARY COURSES

(PHYSICAL SCIENCES)

OFFERED BY THE PHYSICS DEPARTMENT

(for Arts / Commerce / Social Science / Humanities Students)

(1) These courses are meant for students from arts, commerce, management, sociology, history, and other social science departments.

(2) The number of students may be restricted depending on the available classroom or laboratory facilities.

(3) A minimum of 10 students should register to offer the minor papers.

(4) Any ONE course from the list below will be floated.

Type	*Offered in*	*Course Code*	*Credits*	*Title of the Course*
MDC	Odd	PHYS 115	3	Science and Society
MDC	Even	PHYS 125	3	Physics of Energy and Materials
MDC	Odd	PHYS 215	3	Astronomy for Beginners
MDC	Even	PHYS 225	3	Physics of the Environment

PART – V

COURSE STRUCTURE

(Semester-wise Overview of all Subjects together)

SEMESTER – I

Type of Course	*Course Code*	*Credits*	*Title of the Course*	*Offered by Department*
SEC	PHYS 110	3	Physics Laboratory – I	Physics
MAJ	PHYS 111	4	Mechanics	Physics
MIN		4	Chemistry Minor – I *Suggested: Essentials of Chemistry-I*	Chemistry
MDC		3	Multi-disciplinary Paper – I	
AEC		3	English – I	English
VAC		2	Understanding India	
VAC		2	Environmental Sciences	
	Total	**21**		

SEMESTER – II

Type of Course	*Course Code*	*Credits*	*Title of the Course*	*Offered by Department*
SEC	PHYS 120	3	Physics Laboratory – II	Physics
MAJ	PHYS 121	4	Classical Thermodynamics	Physics
MIN		4	Chemistry Minor – II *Suggested: Essentials of Chemistry-II*	Chemistry
MDC		3	Multi-disciplinary Paper – II	
MIL		3	Language Paper – I	
VAC		2	Yoga / Physical Education	
VAC		2	Digital Technologies	
	Total	**21**		

SEMESTER – III

Type of Course	*Course Code*	*Credits*	*Title of the Course*	*Offered by Department*
SEC	PHYS 210	3	Physics Laboratory – III	Physics
MAJ	PHYS 211	4	Acoustics and Oscillations	Physics
MAJ	PHYS 212	4	Electric Circuits Theory	Physics
MIN		4	Mathematics Minor – I *Suggested: Calculus of Several Variables*	Mathematics
MDC		3	Multi-disciplinary Paper – III	
AEC		3	English – II	English
	Total	**21**		

SEMESTER – IV

Type of Course	*Course Code*	*Credits*	*Title of the Course*	*Offered by Department*
SEC	PHYS 220	3	Physics Laboratory – IV	Physics
MAJ	PHYS 221	4	Classical Optics	Physics
MAJ	PHYS 222	4	Analog and Digital Electronics	Physics
MIN		4	Mathematics Minor – II *Suggested: Linear Algebra*	Mathematics
MIN		4	Mathematics Minor – III *Suggested: Differential Equations*	Mathematics
MIL		3	Language Paper – II	
COM		2	(Community Engagement)	
	Total	**24**		

SEMESTER – V

Type of Course	***Course Code***	***Credits***	***Title of the Course***	***Offered by Department***
INT	PHYS 310	4	Internship with Viva-voce	Physics
MAJ	PHYS 311	4	Modern Optics	Physics
MAJ	PHYS 312	4	Elements of Electromagnetics	Physics
MAJ	PHYS 313	4	Modern Physics	Physics
MIN		4	Mathematics Minor – IV *Suggested: Vector Calculus*	Mathematics
MIN		4	Chemistry Minor – III *Suggested: Practice of Chemistry – I*	Chemistry
		24		

SEMESTER – VI*

Type of Course	***Course Code***	***Credits***	***Title of the Course***	***Offered by Department***
SEC	PHYS 320	3	Physics Laboratory – V	Physics
MAJ	PHYS 321	4	Atomic Spectra	Physics
MAJ	PHYS 322	4	Materials Science	Physics
MAJ	PHYS 323	4	Elements of Nuclear Physics	Physics
MIN		4	Mathematics Minor – V *Suggested: Introductory Complex Analysis*	Mathematics
MIN		4	Chemistry Minor – IV *Suggested: Practice of Chemistry – II*	Chemistry
	Total	**23**		

* Students who secure a minimum CGPA of 7.50 in the first six semesters and have cleared arrears (if any) are eligible to undertake research project work in the fourth year. Others shall take coursework instead of the project work in the fourth year.

SEMESTER – VII

Type of Course	*Course Code*	*Credits*	*Title of the Course*
SEC	PHYS 410	3	Advanced Physics Laboratory
MAJ	PHYS 411	4	Mathematical Physics – I
MAJ	PHYS 412	4	Classical Mechanics
MAJ	PHYS 413	4	Quantum Mechanics – I
MAJ	PHYS 414	4	Electronic Devices and Circuits
MAJ	PHYS 415	4	Solid State Physics – I
		23	

SEMESTER – VIII

Type of Course	*Course Code*	*Credits*	*Title of the Course*
MAJ	PHYS 421	4	Statistical Physics – I
MAJ	PHYS 422	4	Classical Electrodynamics
MAJ	PHYS 423	4	Atomic and Molecular Physics
PRO	PHYS 420	12	BSc Honours (UG) Research Dissertation Project*
	(Project Work or in-lieu course work as below)		
MAJ	PHYS 424*	4	Mathematical Physics – II
MAJ	PHYS 425*	4	Solid State Physics – II
MAJ	PHYS 426*	4	Nonlinear Optics
	Total	**24**	

* Candidates not doing project work should take coursework for 12 credits instead of project work.

PART – VI

EVALUATION SCHEME

Laboratory / Practical Exams

Internal Assessment:	75 marks, which includes record marks.
End Semester Exam:	25 marks

Theory Exams

Internal Assessment:	40 marks. (Two internal tests and one assignment.)
End Semester Exam:	60 marks.
Question Paper model:	As given below.

END-SEMESTER EXAM QUESTION PAPER PATTERN

Maximum Time: 3 hours | *Total Marks:* 60

PART - A - Give Short Answers.

Each question carries one mark. [5 x 2 = 10 marks]

Question 1 from Unit - I
Question 2 from Unit - II
Question 3 from Unit - III
Question 4 from Unit - IV
Question 5 from Unit - V

PART - B - Give Very Detailed Answers

(Answer any two subquestions from each unit. [5 x (5 + 5) = 50 marks]

Unit - I

Question 6 (A): Derivation / Bookwork type question. [5 marks]
Question 6 (B): Derivation / Problem-Solving type question. [5 marks]
Question 6 (C): Problem Solving (numerical or analytical). [5 marks]

Unit - II

Question 7 (A): Derivation / Bookwork type question. [5 marks]
Question 7 (B): Derivation / Problem Solving type question. [5 marks]
Question 7 (C): Problem Solving (numerical or analytical). [5 marks]

Unit - III

Question 8 (A): Derivation / Bookwork type question. [5 marks]
Question 8 (B): Derivation / Problem-Solving type question. [5 marks]
Question 8 (C): Problem Solving (numerical or analytical). [5 marks]

Unit - IV

Question 9 (A): Derivation / Bookwork type question. [5 marks]
Question 9 (B): Derivation / Problem-Solving type question. [5 marks]
Question 9 (C): Problem Solving (numerical or analytical). [5 marks]

Unit - V*

Question 10 (A): Derivation / Bookwork type question. [5 marks]
Question 10 (B): Derivation / Problem Solving type question. [5 marks]
Question 10 (C): Problem Solving (numerical or analytical). [5 marks]

** If the 5th unit is unavailable in the syllabus, then a mixture of questions may be taken from all units. For example, Q 10(A) can be from unit-1, then Q 10(B) from unit-3, and Q 10 (C) may be from unit-4.*

*** * * End of Question Paper * * ***

PART – VII

DETAILED SYLLABUS

OF

SKILL ENHANCEMENT COURSES

(Laboratory Courses for Physics Department Students)

SKILL ENHANCEMENT COURSE – 1

PHYS 110 – PHYSICS LABORATORY – I **(3 CREDITS LAB)**

(choose any ten experiments)

1. Simple pendulum.
2. Moment of inertia of flywheel.
3. Bar pendulum.
4. Study of the moment of a couple.
5. Torsion pendulum
6. Kater's pendulum.
7. Linear air track.
8. Study of gyroscope.
9. Inclined plane analysis.
10. Bifilar pendulum.
11. Free fall study.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith. Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

SKILL ENHANCEMENT COURSE – 2

PHYS 120 – PHYSICS LAB – II **(3 CREDITS LAB)**

(choose any ten experiments)

1. Thermal conduction of poor conductor.
2. Study of thermocouple.
3. Specific heat by the method of cooling.
4. Joule's calorimeter.
5. Latent heat of fusion of ice by the method of mixtures.
6. Specific heat of bad conductor.
7. Specific heat of liquid using ice.
8. Determination of Stefan constant.
9. Study of the Boltzmann curve.
10. Thermal conductivity of glass.
11. Study of cooling curve.
12. Forbe's method for good conductor.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith E. V. Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

SKILL ENHANCEMENT COURSE – 3

PHYS 210 – PHYSICS LAB – III **(3 CREDITS LAB)**

(Choose any ten experiments from the list below.)

1. Nonlinear torsion by weights
2. Frequency of tuning fork by sonometer.
3. Melde's string.
4. Calibration of ammeter using potentiometer.
5. Calibration of voltmeter using potentiometer.
6. Study of vibration magnetometer.
7. Surface tension by capillary rise.
8. Surface tension by method of drops.
9. Viscosity of liquids by Poiseuille's method.
10. Comparison of viscosities of two liquids by capillary flow method.
11. Determination of Young's modulus by non-uniform bending using single optic lever.
12. Determination of rigidity modulus by static torsion method.
13. Wheatstone's bridge.
14. The specific resistance of a metal wire by meter bridge.
15. Determination of unknown resistance by Carey-Foster bridge.
16. Resistance measurement by ballistic galvanometer.
17. Figure of merit of a ballistic galvanometer.
18. Comparison of resistances using a ballistic galvanometer.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith, Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

SKILL ENHANCEMENT COURSE – 4

PHYS 220 – PHYSICS LAB – IV **(3 CREDITS LAB)**

(*Choose any ten experiments from the list below.)*

1. Determination of e/m by Millikan's method.
2. Determination of e/m using Thomson's method.
3. Determination of Planck's constant.
4. Verification of Norton's theorem.
5. Verification of Thevenin's theorem.
6. Verification of superposition theorem.
7. Verification of reciprocity theorem.
8. Study of CRO fundamentals.
9. Study of passive filter (a) waveform and (b) frequency response.
10. Study of RC circuit.
11. Study of LCR circuit.
12. Study of LC circuit.
13. Frequency response of series LCR circuit.
14. Frequency response of parallel LCR circuit.
15. Study of AC bridges.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith E. V. Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

SKILL ENHANCEMENT COURSE – 5

PHYS 320 – PHYSICS LAB – V **(3 CREDITS LAB)**

(*Choose any ten experiments from the list below)*

1. Dispersive power and linear dispersion in prism using a cross-wired eyepiece.
2. Study of interference fringes in biprism arrangement.
3. Use of Newton's ring to determine the radius of curvature.
4. Michelson's interferometer.
5. Diffraction of light with circular aperture using He-Ne laser.
6. Fraunhofer diffraction at a single slit using a He-Ne laser.
7. Minimum deviation and first-order spectra of grating.
8. Determination of wavelength of He-Ne laser using meter scale.
9. Fraunhoffer diffraction pattern of a mesh.
10. The pitch of the screw gauge using Fraunhofer diffraction.
11. Measure the thickness of the sleeve using diffraction.
12. Specific rotation of sugar solution by a polarimeter.
13. Study of transmission grating.
14. Verification of Malus law using half and quarter wave plate.
15. Use of Fresnel zone plate.
16. Study of narrow-angle prism.
17. Fresnel diffraction at a single slit.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith. Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

SKILL ENHANCEMENT COURSE – 6

PHYS 410 - ADVANCED PHYSICS LABORATORY (3 CREDITS LAB)

(Choose five from General and five from Electronics experiments)

General Experiments:

1. Resistivity measurement by four probe method.
2. Study of Frank Hertz experiment.
3. Study of ferroelectric phase transition.
4. Study of Hall effect.
5. Constant Deviation Spectrometer.
6. Hysteresis loop of ferromagnetic materials.
7. Determination of magnetic susceptibility of a solid by Guoy's method.
8. Photoconductivity
9. Dielectric constant
10. Michelson Interferometer
11. Diffraction grating experiment
12. Zeeman Effect

Electronics Experiments

1. BJT – Common emitter amplifier.
1. BJT– Two-stage RC-coupled amplifier.
2. Characteristics of FET.
3. Study of unijunction transistor.
4. Study of phase shift oscillator.
5. Study of Hartley oscillator.
6. Study of Colpitt's oscillator.
7. Operational amplifier characteristics.
8. Frequency response of an operational amplifier.
9. Configurations of an operational amplifier.

Text Book

Lab Manual, Department of Physics, Pondicherry University.

Suggested Readings

[1] Rajopadhye and Purohit. A Text Book of Experimental Physics.
[2] Hayes and Horowitz. Students Manual for the Art of Electronics. Cambridge University Press.
[3] Sanish Kumar Gosh. A Text Book of Practical Physics. New Central Books.
[4] Holman. Experimental methods for engineers. Tata McGraw Hill.
[5] Maheswari. Laboratory manual for introductory electronics experiments. New Age International.
[6] Srinivasan and Balakrishnan. A textbook of practical physics. Vols. I, II. S. Viswanathan Pub.
[7] Chattopadhyay and Ratshit. An Advanced Course in Practical Physics. New Central Books.
[8] Ghosh. Advanced Practical Physics. 2-volume set.Sreedhar Publishers.

PART – VIII

DETAILED SYLLABUS

OF

MAJOR PAPERS

Offered by the Physics Department

(for Physics Department Students)

PHYS 111 – MECHANICS (4 CREDITS / 1 TUTORIAL)

Unit – I: FOUNDATIONS (12 hours)
Divergence, curl, gradient – Cartesian, cylindrical, and spherical coordinate systems - Static and dynamic equilibrium under forces and torques – Lami's theorem and problems based on it – Calculation of acceleration of sliding objects down an inclined plane – Atwood machine (pulley) problems – Defining couple and moment of a couple – Resultant of several coplanar forces – Equilibrium of a rigid body under coplanar forces – Period of oscillation of the simple pendulum for large oscillations (Jacobi-Elliptic function) - Equations of motion in two, and three dimensions using cartesian, cylindrical polar (circular motion), and spherical polar coordinate systems - Variable mass systems – Problems solving.

Unit – II: CENTRAL FORCE PROBLEM (12 hours)
Equation of circle, ellipse, parabola in cartesian coordinates, and their corresponding equations in polar coordinates – Equation of spiral – Definition of central force – Kepler problem and central orbits – Derivation of equation of motion in polar coordinates - Turning points in potential energy curve – Obtaining the equation of circular and elliptic orbits - Escape velocity and application to geostationary satellites - Gravitational potential and field due to spherical shell and solid sphere – Problems solving.

Unit – III: RIGID BODY MOTION (12 hours)
Rigid body - Degrees of freedom - Relation between angular momentum, angular velocity, and moment of inertia – Parallel and perpendicular axes theorems - Calculation of moments of inertia of (i) a circular ring, (ii) circular lamina, (iii) solid sphere, (iv) spherical shell, (v) solid cone - Angular momentum of a rigid body – Rolling of circular disc down an inclined plane - Uniformly rotating frame of reference - Centrifugal and Coriolis forces – Problems solving.

Unit – IV: SYSTEMS OF PARTICLES (12 hours)
Work energy theorem - Force as the gradient of a scalar field - Conservative force - Potential energy curves - Stable and unstable equilibrium - Energy of systems of particles - Calculation of center of mass of geometrical objects like (i) arc of a circle, (ii) rectangle with a cavity, (iii) triangle, (iv) solid hemisphere, (v) solid cone, (vi) circular plate having a circular hole – Equation of motion of the center of mass for systems of particles - Conservation laws for systems of particles – Problems solving.

Unit – V: IMPACT AND COLLISION (12 hours)
Elastic and inelastic collisions – Direct and oblique impacts - Newton's experimental law on the coefficient of restitution - Motion of two smooth bodies perpendicular to the line of impact – conservation of momentum in collisions - Direct impact of two spheres - Loss of kinetic energy due to direct impact - Oblique impact of two spheres - Loss of kinetic energy by oblique impact - Calculation of coefficient of restitution - Ballistic pendulum – Laboratory frame of reference - Center of mass coordinate system - Relation between laboratory and center-of-mass systems – Problems solving.

Textbooks
[1] David Morin. Introduction to Classical Mechanics. Cambridge University Press.
[2] P Duraipandian and M Jayapragasam. Mechanics, S. Chand.
[2] Kleppner and Kolenkow. An Introduction to Mechanics, McGraw Hill.

Supplementary Readings
[1] G.R. Fowles and G.L. Cassiday. Analytical Mechanics, Cengage Learning.
[2] S.N. Maiti and D.P. Raychaudhuri, Classical Mechanics. New Age.
[3] K Symon. Mechanics, Pearson Education India.
[4] Kibble and Berkshire, Classical Mechanics, Imperial College Press.
[5] A P French, Newtonian Mechanics, MIT Series, Norton Publishers.

PHYS 121 – CLASSICAL THERMODYNAMICS (4 CREDITS / 1 TUTORIAL)

Unit – I (12 hours)

Extensive and intensive variables - Thermodynamic equilibrium - Zeroth law - State functions - Relations between partial derivatives – Exact differentials – Internal energy function - Differential form of first law and applications - Quasi-static processes - Relation between heat capacities CP and CV - Work done during isothermal and adiabatic processes - Compressibility and expansion coefficients - Second law - Reversible and irreversible processes with examples - Heat engines - Carnot cycle, Carnot engine, efficiency, and coefficient of performance - Second law as Kelvin-Planck statement and its equivalence to Clausius statement – Problems solving.

Unit – II (12 hours)

Entropy - Clausius theorem - Clausius inequality - Second law in terms of entropy - Entropy of a perfect gas - Principle of increase of entropy - Entropy changes in reversible and irreversible processes with examples – Calculation of entropy change in ice-water transformation and similar examples – Entropy of the Universe - Temperature-entropy (TS) diagrams for thermodynamic cycles - Third law of thermodynamics - Unattainability of absolute zero – Problems solving.

Unit – III (12 hours)

Thermodynamic potentials - Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's free energy - Properties and applications - Magnetic work and cooling due to adiabatic demagnetization - First and second-order phase transitions with examples - Ehrenfest classification - Maxwell's thermodynamic relations, derivation, and applications - Clausius Clapeyron equation – Difference between heat capacities CP and CV – The TdS Equation - Joule-Kelvin coefficient for ideal and Van der Waal gases - Energy equations - Change in temperature during the adiabatic process - Joule's experiment – Free adiabatic expansion of a perfect gas – Problems solving.

Unit – IV (12 hours)

Maxwell-Boltzmann distribution of velocities in an ideal gas and its experimental verification - Doppler broadening of spectral lines - Mean, RMS, and most probable speeds - Degrees of freedom – The law of equipartition of energy without proof - Specific heat of mono-, di- and tri-atomic gases - Molecular collisions - Collision probability - Estimates of mean free path – Problems solving.

Unit – V (12 hours)

Applications of kinetic theory - Derivation of coefficient of viscosity of gas using kinetic theory - Derivation of thermal conductivity of gas using kinetic theory - Calculation of coefficient of self-diffusion of gas using kinetic theory – Behavior of real gases - Deviations from the ideal gas equation - The virial equation - Andrew's experiments on carbon dioxide gas - Continuity of liquid and gaseous state – Boyle temperature - Van der Waal's equation of state for real gases - Law of corresponding states - Comparison with experimental curves – Problems solving.

Textbooks

[1] Zemansky, Dittman. Heat and Thermodynamics, McGraw-Hill.
[2] Sears and Salinger. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa.
[3] Blundell and Blundell. Concepts in Thermal Physics, Oxford University Press.
[4] H B Callen. Thermodynamics and An Introduction to Thermostatics, Wiley.
[5] P K Nag. Basic and Applied Thermodynamics. McGraw Hill.

Supplementary Readings

[1] C J Adkins, Equilibrium Thermodynamics, Cambridge University Press.
[2] M Kaufman, Principles of Thermodynamics, CRC Press.
[3] L B Leob, Kinetic theory of gases, Dover.
[4] A B Pippard. Elements of Classical Thermodynamics. Cambridge University Press.
[5] C S Helrich, Modern Thermodynamics with Statistical Mechanics, Springer.

PHYS 211 – ACOUSTICS AND OSCILLATIONS (4 CREDITS / 1 TUTORIAL)

Unit–I (12 hours)

Classification of differential equations as linear, nonlinear, homogeneous, inhomogeneous and coupled equations - Distinction between initial value and boundary value problems - Method of integrating factor – Method of separation of variables – Second order differential equations – Solving Homogeneous and inhomogeneous equations with variable coefficients - Wronskian and principle of superposition - Method of undetermined coefficients - Method of variation of parameters - Applications to electrical and mechanical vibrations and forced oscillations - Problems solving.

Unit – II (12 hours)

Harmonic oscillations – Calculation of kinetic energy, potential energy, total energy, and their time-average values - Damped and Forced oscillations – Solution of damped and forced oscillators - Transient and steady states – Resonance and sharpness of resonance - Power dissipation and quality factor - Examples of electrical (vibration) systems like LCR resonance– Problems solving.

Unit – III (12 hours)

Superposition of two collinear harmonic oscillations - Superposition of two perpendicular harmonic oscillations for phase difference - Graphical and analytical methods - Lissajous figures with equal and unequal frequency and their uses - Superposition of a large number of simple harmonic vibrations of equal amplitude and uniform phase difference – Phase and group velocities and their relationship - Coupled oscillations – Problems solving.

Unit – IV (12 hours)

Classification of partial differential equations (PDE) – Derivation of the wave equation (PDE) - The velocity of transverse vibrations of stretched strings - Standing stationary waves in a string - Fixed and free ends - Analytical solution - Plane wave representation in two and three-dimensions – Wave equation in two dimensions – Energy density of vibrating string – Transfer of energy - Normal modes of stretched strings – Plucked and struck strings - Solution by the method of separation of variables – Normal modes in two-dimensional case – Reflection and transmission of a three-dimensional wave at a plane boundary – Example of total internal reflection and evanescent waves – Problems solving.

Unit – V (12 hours)

Acoustics – Reflection, refraction, and interference of sound waves – Beats – Standing waves – Doppler effect in acoustics - Sound waves in gases – Velocity of sound in gases – Energy distribution in sound waves – Intensity of sound waves – Longitudinal waves in a solid medium - Example of earthquake – Reflection and transmission of sound waves at boundaries – Eigenmodes and eigenfrequency of vibrating strings – Melde's experiments – Diffraction of sound waves – Introduction to acoustic transducers – Acoustics of auditoriums and halls – Reverberation time – Problems solving.

Textbooks

[1] Boyce and Diprima, Elementary Differential Equations, Wiley.
[2] H J Pain. The Physics of Vibrations and Waves, John Wiley.
[3] L E Kinsler and A. R. Frey. Fundamentals of Acoustics, John Wiley.
[4] D. P. Roychowdhury. Advanced Acoustics, Chayan Publisher.
[5] N. K. Bajaj. Waves and Oscillations. Tata McGraw Hill.
[6] R.N. Chaudhuri. Waves and Oscillations, New Age International.

Supplementary Readings

[1] M. Ghosh and D. Bhattacharya. A Textbook of Oscillations, Waves, and Acoustics. S. Chand.
[2] K.U. Ingard. Fundamentals of Waves and Oscillations, Cambridge University Press.
[3] A.I. Vistnes. Physics of Oscillations and Waves. Springer.
[4] G.C. King. Vibrations and Waves, Wiley.
[5] J. Franklin. Mathematical Methods for Oscillations and Waves, Cambridge University Press.
[6] I G Main. Vibrations and Waves in Physics, Cambridge University Press.

PHYS 212: ELECTRIC CIRCUITS THEORY **(4 CREDITS / 1 TUTORIAL)**

UNIT – I: Series-Parallel Networks **12 hours**

Review of current electricity – Kirchhoff's laws – Ladder networks – Current sources – Conversion of current source to voltage source – Current sources in series and parallel – Mesh analysis – Nodal analysis – Bridge networks – Y to Delta and Delta to Y conversion – Problems solving.

UNIT – II: Network Theorems **12 hours**

Superposition theorem – Thevenin's theorem – Norton's theorem – Maximum power transfer theorem - Millman's theorem – Substitution theorem – Reciprocity theorem – Problems solving.

UNIT – III: Capacitative, Inductive, Magnetic Circuits **12 hours**

Transients in capacitative networks – Time constant – Capacitor networks – Energy relations – Introduction to Magnetic circuit – Reluctance – Series and parallel magnetic circuits – Analogy between electromotive force (e.m.f) and magnetomotive force (m.m.f) – Inductors – resistor-inductor (RL) transients – Time constant – Problems solving.

UNIT – IV: AC circuits **12 hours**

Introduction to a.c waveforms – Definition of terminology – Average and effective values – Introduction to phasor notation – Response of R, L, and C elements to a sinusoidal signal – Frequency response – Power factor – Series and parallel a.c circuits – Impedance and phase diagram – Voltage divider rule for a.c circuits – Current divider rule for a.c circuits – Power in a.c circuits – The power triangle – Problems solving.

UNIT –V: Resonance **12 hours**

Introduction to resonance – Series LCR resonant circuit – Q-factor – Variation of impedance with frequency – Selectivity of a series resonant circuit – Parallel LCR resonant circuit – Q-factor – Selectivity curves – Application to tuned filters – Bode plots – Problems solving.

Textbooks

[1] Boylestad, Introductory Circuit Analysis, Prentice-Hall.
[2] Alexander and Sadiku, Fundamentals of Electric Circuits, McGraw Hill.

Supplementary Readings

[1] Floyd, Electric Circuit Fundamentals, Prentice-Hall.
[2] Scherz. Practical Electronics for Inventors. McGraw Hill.
[3] Nahvi, Edminister, and Rao, Electric Circuits, Schaum's Outline Series, McGraw Hill.

PHYS 221 – CLASSICAL OPTICS **(4 CREDITS / 1 TUTORIAL)**

UNIT – I: GEOMETRICAL OPTICS **12 hours**

Fermat's principle: Laws of reflection and refraction from Fermat's principle – Principle of extreme path – The aplanatic points of a sphere and other applications – General theory of image formation – Image formation due to reflection and refraction of objects at different positions from curved surfaces – Cardinal points of an optical system – General relationships – Thick lens and lens combinations – Telephoto lenses.

UNIT – II: OPTICAL INSTRUMENTS **12 hours**

Aberration in images – Chromatic aberrations – Achromatic combination of lenses in contact and separated lenses – Monochromatic aberrations and their reduction – Aspherical mirrors and Schmidt corrector plates – Oil immersion objectives – Meniscus lenses – Optical instruments: Entrance and exit pupils – Need for a multiple lens eyepiece – Common type of eyepieces.

UNIT – III: INTERFERENCE **12 hours**

Interference of light: The principle of superposition – Two-slit interference – Coherence requirements for the sources – Localized fringes in thin films – Transition from fringes of equal thickness to those of equal inclination – Michelson interferometer and its uses for determination of wavelength – Wavelength difference and standardization of the meter – Intensity distribution in multiple beam interference – Fabry-Perot interferometer and etalon.

UNIT – IV: FRESNEL DIFFRACTION **12 hours**

Hugens-Fresnel theory – Fresnel's assumptions – Half-period zones of a plane wavefront – Zone plate – Action of zone plate as a convex lens – Circular apertures and obstacles – Straight edge – Explanation of rectilinear propagation – Fresnel's half-period elements of cylindrical wavefront – Fresnel's diffraction at a straight edge, narrow rectangular aperture, around a narrow obstacle, in circular aperture and in opaque circular disc – Cornu spiral and its applications – Babinet's principle.

UNIT – V: FRAUNHOFER DIFFRACTION **12 hours**

Fraunhofer diffraction: Diffraction at a slit, a circular aperture and a circular disc – Resolution of images – Rayleigh criterion and overlapping of spectral lines – Resolving power of a telescope and a microscope – Grating: Diffraction at N parallel slits – Plane diffraction grating – Concave reflection grating – Angular dispersive power of grating – Comparison of resolving power of gratings and prisms.

Textbooks

[1] Ghatak, Optics, Tata McGraw Hill.
[2] Hecht, Optics, Addison Wesley.
[3] Pedrotti and Pedrotti, Introduction to Optics, Prentice Hall.
[4] K K Sharma, Optics, Elsevier.
[5] B Ghosh and K G Mazumdar, A Text Book on Light, Sreedhar Publishers.
[6] Subrahmaniyam, Brijlal, and Avadhanulu. A Textbook of Optics, S. Chand.

Supplementary Readings

[1] Jenkins and White, Fundamental of Optics, McGraw-Hill.
[2] Born and Wolf, Optics, Pergamon Press.
[3] Meller, Optics, Oxford University Press.
[4] Longhurst, Geometrical and Physical Optics, Longmans.
[5] Feynman. The Feynman Lectures on Physics, 3-volume set, Narosa.
[6] B B Laud, Lasers and Non-linear Optics, Wiley Eastern.
[7] Smith and Thomson, Optics, John Wiley.

PHYS 222 – ANALOG AND DIGITAL ELECTRONICS (4 CREDITS / 1 TUTORIAL)

Unit-I: Diodes 12 hours

PN diode with (i) no external bias, (ii) reverse bias and (iii) forward bias – Current-voltage characteristics – Comparison of characteristics of Ge, Si, and GaAs diodes –AC or dynamic resistance of diode – Notation for various diodes –Zener diode characteristics – Circuits containing series and parallel combinations of diodes – Sinusoidal input to diode circuits – Solving half-wave and full-wave (bridge network) rectifying circuits – Shockley model – Applications as clippers, limiters, clampers, and regulated power supply.

Unit-II: BJT: DC Biasing 12 hours

Bipolar junction transistor (BJT) structures - Active and saturation regions - Characteristics of BJT in CE, CB, and CC configurations – I/O characteristics - Load line analysis, Operating point - DC Biasing: Fixed bias, Emitter bias, Voltage divider bias - Collector feedback – Emitter-follower configuration – Common-base stability factor - Bias compensation

Unit-III: BJT AC Analysis 12 hours

Two-port analysis of a transistor – Transistor hybrid model - Analysis of a transistor amplifier circuit using *h*-parameters - Thevenin's and Norton's theorems and corollaries - Emitter follower - Linear analysis of a transistor circuit - Miller theorem and its dual - Simplified hybrid models of CE, CE amplifier with emitter resistance.

Unit - IV: Amplifiers and Oscillators 12 hours

Classification of amplifiers - Single-stage and two-stage RC coupled amplifiers – Frequency response, bandwidth, and rise time - Flat band equivalent circuits – Cascade connections - Barkhausen condition - OPAMP and applications: Inverting and non-inverting amplifiers - Sinusoidal oscillators: Phase shift, Wein bridge, Colpitt, and Hartley oscillators.

Unit -V: Digital Fundamentals 12 hours

Boolean algebra: Logic Gates AND, OR, NOT, NAND, NOR exclusive OR – Truth tables - Combination of gates - de Morgan's theorem - Flip Flops; S-R, J-K, Master-slave, S-R and Master-slave J-K Flip Flop counters, synchronous, asynchronous, Modulo-n-counters-shift registers; Serial to parallel and vice-versa, universal shift registers, ring counter - Logic circuits using standard TTL and CMOS-Combinational circuits: Adders, subtractors, multiplexer/demultiplexer, decoder, and encoders.

Text Books

[1] Boylestad and Nashelsky, Electronic Devices and Circuits, Pearson.
[2] Floyd, Digital Fundamentals, Pearson.

Supplementary Reading

[1] Floyd, Electronic Devices, Pearson.
[2] Millman and Hallkias, Integrated Electronics, McGraw Hill.
[3] Ryder, Electronic fundamentals and applications, Prentice-Hall.
[4] Stanley, Electronic Devices: Circuits and Applications, McGraw-Hill.
[5] Malvino and Leach, Digital Principles of Electronics, McGraw Hill.

PHYS 311 –MODERN OPTICS **(4 CREDITS / 1 TUTORIAL)**

UNIT – I: Polarisation and Double Refraction **12 hours**

Production of polarized light – Malus's law – The phenomenon of double refraction and optical rotation – Double refraction in uniaxial crystals - Explanation in terms of electromagnetic theory – Interference of polarized light – Retarder plates - Quarter wave and half wave plate – Change of state of polarization using retarder plates – Optical activity – Rotation of plane of polarization – Origin of optical rotation in liquids and in crystals.

UNIT –II: Complex Refractive Index **12 hours**

Refractive index – Propagation of light in a dielectric medium – Macroscopic polarization in a dielectric medium – Origin of complex refractive index - Significance of real and imaginary components of complex refractive index – Lorentz oscillator model - Theory of dispersion of light – Theory of absorption – Normal and anomalous dispersion – Theory of Rayleigh scattering – Scattering of x-rays and determination of Z of an atom.

UNIT – III: Coherence Properties **12 hours**

Superposition of two electromagnetic waves – Linewidth – Spatial coherence – Complex degree of coherence and fringe visibility in Young's double hole experiment – Laser as a source of coherent light – Concept of population inversion – Einstien's A and B coefficients – Purity of spectral line – Coherence length of a laser emission field – Estimation of laser beam intensity and spectral energy density.

UNIT – IV: Statistical Properties **12 hours**

Statistical properties of random light – Concept of coherence – Interference of partially coherent light – Coherence time and linewidth via Fourier analysis – Spatial coherence and temporal coherence – Michelson-stellar interferometer – Fourier transform spectroscopy – Holography – Introduction theory, requirements, and some applications.

UNIT – V: Fiber Optics **12 hours**

Introduction to optical Fibers – Importance of glass as a medium – Coherent bundle – Numerical aperture – Single and multimode fibers – Pulse dispersion – Attenuation in optical fibers – Power law profile - Waveguide dispersion – Dispersion compensating fibers – Dispersion and maximum bit rates.

Textbooks

[1] Ghatak, Optics, Tata McGraw Hill.
[2] Hecht, Optics, Addison Wesley.
[3] Pedrotti and Pedrotti, Introduction to Optics, Prentice Hall.
[4] K K Sharma, Optics, Elsevier.
[5] B Ghosh and K G Mazumdar, A Text Book on Light, Sreedhar Publishers.
[6] Subrahmaniyam, Brijlal, and Avadhanulu. A Textbook of Optics, S. Chand.

Supplementary Readings

[1] Jenkins and White, Fundamental of Optics, McGraw-Hill.
[2] Born and Wolf, Optics, Pergamon Press.
[3] Meller, Optics, Oxford University Press.
[4] Longhurst, Geometrical and Physical Optics, Longmans.
[5] Feynman. The Feynman Lectures on Physics, 3-volume set, Narosa.
[6] B B Laud, Lasers and Non-linear Optics, Wiley Eastern.
[7] Smith and Thomson, Optics, John Wiley.

PHYS 312 – ELEMENTS OF ELECTROMAGNETICS (4 CREDITS / 1 TUTORIAL)

Unit – I (12 hours)

Cylindrical and spherical coordinate unit vectors – Vector calculus in the curvilinear coordinate system – Gauss divergence theorem and Stokes theorem of vectors and their significances – Electrostatics: Defining linear, surface and volume charge density - Electric field due to an infinitely long line charge, a sheet of charge, a ring of charge, a charged disk, an electric dipole, and other charge distributions – Derivation of Gauss's law from Coulomb's law – Calculation of electric field everywhere due to symmetric charge distributions like (i) infinite sheet of charge, (ii) uniformly charged solid sphere, (iii) uniformly charged spherical shell, (iv) solid cylinder, and similar configurations – Calculation of dipole moment due to an electric dipole – Problems solving.

Unit – II (12 hours)

Discontinuity of electric field on the surface of a conductor – Convection and conduction current and deriving Ohms law $J = \sigma E$. – Continuity equation and relaxation time - Dielectric polarization – Dielectric breakdown – Electric susceptibility and permittivity - Gauss's law in the presence of linear dielectrics – Capacitors with dielectrics - Calculating the capacitance (in the presence of dielectrics) of a parallel plate capacitor, a cylindrical capacitor, a spherical capacitor, coaxial cylindrical capacitor, concentric spherical capacitor and for an isolated spherical capacitor - Bound charges, Displacement density vector – Problems solving.

Unit – III (12 hours)

Laplace equation in cartesian, cylindrical, and spherical coordinate systems – Poisson equation - Solution of Laplace's equation for simple cases - The electric potential inside and outside of a spherical shell of charge - Electric potential due to a system of discrete charges and continuous charge distributions – Potential gradient – Derivation of energy density in an electrostatic field –Potential energy of an electric dipole in an electric field – Calculation of energy density due to symmetric charge distributions – Problems solving.

Unit – IV (12 hours)

Comparison of electric and magnetic fields and their SI units – Biot-Savart law in vector form – Calculation of divergence of the magnetic field – Introduction to magnetic vector potential – Ampere's circuital law – Calculation of magnetic field due to (i) infinite line current, (ii) infinite sheet of current, (iii) toroid, and similar current configurations – Non-existence of magnetic monopoles – Equivalence of current-carrying loop and a magnetic dipole – Energy stored in a magnetic field – Calculation of magnetic energy density - Lorentz force equation – Dynamics of charged particles in electric and magnetic fields - Linear homogeneous isotropic magnetic materials – Magnetic field inside magnetic materials – Ampere's law in material media – Motional emf – Eddy currents - Self-induction and mutual induction – Calculation of self-inductance of (i) infinitely long solenoid, (ii) coaxial cable.

Unit – V (12 hours)

Classification of partial differential equations into elliptic, parabolic, and hyperbolic equations - Establishing four Maxwell's equations - Derivation of the electromagnetic wave equation from Maxwell's equation – Calculation of speed of light from Maxwell's equation - Poynting theorem - Reflection and refraction at a dielectric interface, transmission, and reflection coefficients (normal incidence only) – Problems solving.

Textbooks

[1] Sadiku, Elements of Electromagnetics, Oxford University Press.
[2] Edward M. Purcell. Electricity and Magnetism. McGraw-Hill.
[4] Fleisch. A student's guide to Maxwell's equations, Cambridge University Press.

Supplementary Readings

[1] Griffiths, Introduction to Electrodynamics, Pearson.
[2] Lorrain, Corson and Lorrain, Electromagnetic Fields and Waves, Freeman.
[3] Kraus and Carver, Electromagnetics, McGraw-Hill.

PHYS 313 – MODERN PHYSICS (4 CREDITS / 1 TUTORIAL)

Unit – I: Wave or Particle? (12 hours)
Blackbody radiation – Wien's displacement law – Spectral distribution function – Calculation of temperature of a star – Rayleigh-Jeans equation – Planck's quantum hypothesis - Plots of Planck's law versus the Rayleigh-Jeans law – Integration of Planck's distribution function and Stefan-Boltzmann law – Calculation of peak wavelength – Calculation of average energy of Planck's oscillator - Photoelectric effect – Calculation of workfunction of metals – Calculation of the number of photons incident per unit area – Compton effect and Compton scattering – Wavelike properties of particles – de Broglie hypothesis - Davisson-Germer experiment – Matter waves and wave packet – Group velocity using wave equation - Relation between group velocity and phase velocity - Motion of a Gaussian wave packet - Two-slit interference experiments with photons and electrons.

Unit – II: Wave Mechanics (12 hours)
Probabilistic interpretation of matter waves – Heisenberg uncertainty principle – Calculation of minimum energy and the spectral line-width using uncertainty principle – Wave-particle duality – Reason for quantum particle not following a trajectory – Schrödinger equation from conservation of energy – Separation of variables for the Schrodinger equation - Time-independent Schrodinger equation – Postulates of quantum mechanics – Calculation of probabilities, expectation values and energy using operators – Particle in a one and three-dimensional boxes (infinite square well) – Concept of degeneracy – Reflection and transmission at a finite step potential (finite square well tunneling) - Differential equation for the quantum harmonic oscillator (QHO) and its solution – Calculation of expectation values and energy of QHO - Problems solving.

Unit - III: Special Theory of Relativity (12 hours)
Michelson-Morley experiment – Einstein's postulates – Inertial frames and Galilean invariance – Lorenz transformation – Time dilation – Length contraction – Twin paradox – Velocity addition – Relativistic momentum and energy – Calculation of momentum and total energy of proton moving at relativistic speeds – Mass energy equivalence and binding energy – Relativistic Doppler effect - Ives-Stilwell experiment - Electric and magnetic fields under special relativity – Problems solving.

Unit - IV: Basics of Statistics (12 hours)
Discrete and continuous random variables – Probability distribution function and density function for (i) uniform, (ii) binomial, (iii) Poisson, and (iv) Gaussian distributions - Calculation of (a) expected values, (b) standard deviation, (c) skewness, (d) kurtosis, (e) higher moments of statistical distributions – Central limit theorem – Law of large numbers – Problems solving.

Unit - V: Statistical Physics (12 hours)
Statistical Physics: Concept of statistical ensemble, phase space, and microstates – Postulates of statistical physics – Calculation of density of states in a gas of particles - Maxwell Boltzmann, Fermi-Dirac, and Bose-Einstein statistics – Calculation of number of microstates - Random-walk problem in 1D and 2D - Calculation of mean and dispersion - Problems solving.

Textbooks
[1] Soong, Fundamentals of Probability and Statistics for Engineers, Wiley.
[2] Tipler and Llewellyn. Modern Physics. W.H. Freeman & Co.
[3] K.S. Krane, Modern Physics, Wiley.
[4] David Morin, Special Relativity for the Beginner, CreateSpace Publishing.
[5] Robert Resnick, Special Theory of Relativity, John Wiley.
Supplementary Readings
[1] Richtmyer, Kennard, Cooper, Introduction to Modern Physics, Tata McGraw Hill.
[2] Walecka, Introduction to Modern Physics. World Scientific.
[3] Beiser, Concepts of Modern Physics, McGraw-Hill.
[4] Wehr, Richards, Adair, Physics of the Atom, Narosa.
[5] Gautreau and Savin, Schaums Theory and Problems of Modern Physics, McGraw-Hill.

PHYS 321 - ATOMIC SPECTRA **(4 CREDITS / 1 TUTORIAL)**

UNIT – I **15 hours**

Rutherford's Gold foil experiment and atom model – Atomic spectra and basic features – Bohr's atom model – Discrete energy levels – Emission and absorption spectra of the hydrogen atom – Origin of spectral series – Line spectra – Rydberg constant – Ritz combination principle – Sommerfeld's extension of Bohr's theory – Relativistic mass correction – Discovery of heavy hydrogen (deuterium) – Bohr's correspondence principle – Resonance, excitation, and ionization potentials – Spectra of hydrogen-like atoms – Measurements of critical potentials – Franck-Hertz experiment.

UNIT – II **15 hours**

Introduction of atomic spectra for alkali metals – Electron shielding effect on energy levels – Singlet, doublets, triplets, and multiplets in atomic spectra – Vector model of an atom – Relation between quantum numbers, angular momenta and magnetic moments – Space quantization – Spin-orbit *L-S* coupling and *J-J* coupling – Electronic energy level notation according to orbital quantum number – Pauli's exclusion principle – Afbau principle and electron configuration – Valence electrons and core electrons – Spectroscopic notation for ground state configuration – Zeeman effect – Normal and anomalous Zeeman effects – Paschen-Back effect – Stark effect – Stern-Gerlach experiment.

UNIT – III **15 hours**

Production of X-rays – Properties of X-rays – Applications of X-rays – Variation of X-ray intensity with wavelength – Origin of continuous X-radiation – Origin of characteristic X-ray lines – Fine structure of characteristic X-ray lines – Moseley's law and X-ray spectra – Scattering of X-rays – Thomson's theory – Compton scattering – Energy of scattered radiation and recoil electron – Experimental studies of Compton effect – Diffraction of X-rays – Derivation of Bragg's equation – Modification of Bragg's law due to refraction – Introduction to X-ray diffractometer.

UNIT – IV **15 hours**

Ordinary light versus laser light source – Induced absorption – Spontaneous emission – Stimulated emission – Einstein's theory for atomic transitions Induced absorption –Synchroton radiation source – Linewidth and Line shape – Interaction of radiation with matter — Derivation of Planck's radiation formula from Einstein's coefficients – Production of synchrotron radiation – Applications of laser source and synchrotron source for material research – Difference between synchrotron radiation and free electron laser – Introduction to x-ray absorption spectroscopy – Introduction to fluorescence and phosphorescence.

Text Books

[1] H E White, Atomic Spectra, McGraw-Hill.
[2] Svanberg, Atomic and Molecular Spectroscopy, Springer.
[3] Rita Kakkar, Atomic and Molecular Spectroscopy, Cambridge University Press.
[4] Mani and Mehta, Introduction to Modern Physics, Affiliated East-West.
[5] Beiser, Perspectives of Modern Physics, McGraw-Hill
[6] Richmeyer, Kennard, and Cooper, Introduction to Modern Physics, Tata McGraw Hill.
[7] R B Singh, Introduction to Modern Physics. New Age.

Suggested Readings

[1] Taylor and Zafiratos, Modern Physics, PHI Learning.
[2] Serway, Moses, and Moyer, Modern Physics, Cengage Learning.
[3] Kaur and Pickrell, Modern Physics, McGraw Hill.
[4] Banwell and Mccash, Fundamentals for Molecular Spectroscopy, McGraw Hill
[5] A B Gupta and D Ghosh, Atomic and Nuclear Physics, Allied Publishers.
[6] B G Wagh, P S Tambade, S D Aghav, *et al.,* Atomic And Molecular Physics, Nirali Prakashan.
[7] W G Schrenk, Analytical Atomic Spectroscopy, Springer.
[8] J Michael Hollas, Basic Atomic and Molecular Spectroscopy, volume-11, RSC Books.

PHYS 322 – MATERIALS SCIENCE (4 CREDITS / 1 TUTORIAL)

Unit – I: Phase Rule (12 hours)
Classification of crystalline and amorphous materials - Structure-property relationships – Solubility limit and microstructure - Stability and meta stability - Thermodynamic functions and kinetics of phase transformations - Phase diagrams, Gibb's phase rule - Lever rule - Cooling curve – One and two-component solid solutions – Eutectic, peritectic and monotectic systems - Microstructural changes during cooling – Examples of binary phase diagrams - Polymorphism and allotropy.

Unit – II: Crystal Structure (12 hours)
Crystals – Classification of crystal systems – Introduction to Bravais lattice – Calculation of distance between crystal planes – Miller indices – Calculation of linear, planar and volume densities – Packing fraction – Ionic crystals, covalent crystals - Van der wall, metallic and dipole bonding - Single crystals - Techniques of growing single crystals like melt growth – Basics of thin films – X-ray sources and diffraction – Optical techniques for characterization.

Unit – III: Defects and Diffusion (12 hours)
Impurities in solids – Vacancies and interstitials - Point and line defects – Edge and screw dislocations – Planar defects and grain boundaries - Elastic deformation – Ductile and brittle fracture – Plastic deformation Slip – Critical shear stress – Effect of lattice defects on mechanical properties – Stress-strain curve – Yield stress - Young's modulus, Poisson ratio, and hardness of materials - Atomic processes in solids – Diffusion and self-diffusion in solids – Vacancy diffusion – Interstitial diffusion - Concentration gradient - Diffusion constant - Fick's laws (first and second law) of diffusion and its applications – Factors affecting diffusion (like temperature) - Problems solving using error function and complementary error functions

Unit – IV: Band Theory (12 hours)
Origin of band gap in solids – Classification of metals, insulators, and semiconductors – Electron mobility – Derivation of electrical conductivity of metals based on Drude theory – Drift velocity of electrons in metals – Matthiessen's rule of electrical resistivity – Variation of resistivity with temperature and due to impurities - Forbidden gap – Semiconductor materials (Ge, Si, GaAs) - Effect of temperature on semi-conductivity – Calculation of carrier density of semiconductors using Hall effect – Introduction to compound semiconductors and bandgap engineering – *n*-type and *p*-type materials – Majority and minority carriers.

Unit – V: Magnetic Materials (12 hours)
Definition of Bohr magneton - Origin of the magnetic moment – Magnetic moment of electrons and of atoms – Classification as dia, para, ferro, anti-ferro, and ferri magnetic materials – Classical theory of paramagnetism – Derivation of Curie-Weiss law – Langevin theory – Basics of quantum theory of paramagnetism – Lande's g-factor – Examples like the salts of transition elements, oxides of rare-earth elements – Molecular field theory of ferromagnetism - Law of corresponding states – Temperature dependence of magnetic susceptibility – Ferromagnetism and ferrimagnetism – Examples with their crystal structures (like cubic ferrites) - Crystalline materials exhibiting ferroelectricity and piezoelectricity – Details of barium titanate structure.

Textbooks
[1] Raghavan, Materials Science and Engineering, Prentice Hall.
[2] Callister and Rethwisch. Materials Science and Engineering, Wiley.
[3] Hummel, Electronic Properties of Materials, Springer.
[4] Cullity and Graham, Introduction to Magnetic Materials, Wiley.
[5] Blackmore, Solid State Physics, Cambridge University Press.
Supplementary Readings
[1] Moffatt, Pearsall, and Wulff, Structure and Properties of Materials, 4-volume set, Wiley.
[2] Smith and Hashemi. Foundations of Materials Science and Engineering. McGraw-Hill
[3] Saka. Introduction to Phase Diagrams in Materials Science. World Scientific.
[4] Askeland and Wright. The Science and Engineering of Materials. Cengage Learning.

PHYS 323 - ELEMENTS OF NUCLEAR PHYSICS (4 CREDITS / 1 TUTORIAL)

Unit I: Introduction to Nucleus 15 hours
Nuclear mass – Nuclear size – Constituents of nucleus – Nuclear Properties – Nuclear charge/mass density – Nature of nucleus (Quantum – Non-relativistic) - Woods-Saxon potential - Nuclear radius – Nuclear spin – Nature of Nuclear forces and range – Mass defect - Binding energy – N/Z plot – Stable nuclei – Yukawa meson theory.

Unit II: Nuclear Models 15 hours
Fermi Gas Model – Liquid drop model – Binding energy curve – Semi-empirical Mass Formula – Significance of different terms in SEMF – Application of SEMF - Most-stable isotope - Magic numbers.

Unit III: Nuclear Processes 15 hours
Unstable nuclei – Q value – Radioactivity – Decay laws –Mean-life – Half-life - Alpha decay – Tunnelling - Beta decay – Energy spectrum – Neutrino hypothesis - Gamma decay – Internal Conversion – Pair production – Nuclear energy - Nuclear fission – Nuclear reactors – Chain reactions - Nuclear fusion – Fusion in the sun.

Unit IV: Elementary Particles 15 hours
Discovery of elementary particles – Classification/properties of elementary particles – Particles and their families - Conservation laws and quantum numbers – Introduction to Fundamental interactions – Basic ideas of Unification of fundamental forces.

Textbooks
[1] Krane, Introductory Nuclear Physics, Wiley.
[2] Kaplan, Nuclear Physics, Narosa.
[3] Ashok Das and Ferbel. Introductory Nuclear and Particle Physics, World Scientific.
[4] Dodd and Gripaios. Idea of Particle Physics, Cambridge University Press.
[5] Beiser. Concepts of Modern Physics, Tata Mc-Graw Hil.
[6] Halliday, Resnick, Walker, Fundamentals of Physics, John Wiley.

Supplementary Readings
[1] Cohen, Concepts of Nuclear Physics, Tata McGraw Hill.
[2] Palash B. Pal, An Introductory Course of Particle Physics.
[3] Kakani and Kakani, Nuclear and Particle Physics, Viva.
[4] Hughes, Elementary Particles, Cambridge University Press.
[5] Bethe and Morrison, Elementary Nuclear Theory, Dover.
[6] Mani and Metha. Introduction to Modern Physics, Affiliated East-West
[7] Richtmyer, Kennard and Cooper, Introduction to Modern Physics, Tata McGraw Hill.
[8] Wehr, Richards, and Adair, Physics of the Atom, Narosa.
[9] Roy and Nigam, Nuclear Physics: Theory and Experiments, New Age.

PHYS 411 - MATHEMATICAL PHYSICS – I (4 CREDITS / 1 TUTORIAL)

Unit I: Differential Equations (15 hours)

Classification of differential equations - Euler equation – Singular points of ODE - Frobenius method and series solution of second order ODE– Orthogonal functions - Strum-Liouville problem and orthogonal eigenfunction expansions – Application to solve boundary value problems - Partial differential equations in the curvilinear (cylindrical and spherical) coordinate systems – Heat equation, wave equation, and Laplace equation in cylindrical and spherical coordinate systems - Method of separation of variables to solve PDE's in 3D curvilinear coordinate systems.

UNIT II: Special Functions (15 hours)

Definition of improper integrals of first and second kind – Beta, Gamma, Delta, and Error functions and evaluation of improper integrals – Stirling's formula - Bessel, Hermite, Legendre, Associated Legendre, and Laguerre differential equations and their solutions by series method – Bessel functions of the first and second kind – Legendre polynomials, Legendre functions of the first and second kind - Spherical harmonics – Orthogonality conditions of special functions - Generating functions, Rodrigue formula, and Recurrence relations - Applications in physics.

Unit III: Complex Variables (15 hours)

The function of a complex variable – Mapping by exponential function – Differentiability and analyticity - Cauchy-Riemann conditions in polar coordinates – Analytic functions and harmonic functions – Logarithmic function and branch cuts – Terminology: Epsilon neighborhood, Open disk, Simple closed curve, Multiply connected domains, Meromorphic function, Entire function – Contour integrals using parametrization – Contour integrals involving branch cuts – Cauchy-Goursat theorem for multiply connected domain – Principle of deformation of contours – Cauchy integral theorem – Cauchy integral formula – *M-L* theorem – Morera theorem – Sequences and series – Absolute and uniform convergence of power series - Taylor, Maclaurin, and Laurent series expansion of complex functions – Circle of convergence and radius of convergence – Taylor theorem – Laurent theorem – Zeros and order of zeros – Simple pole and higher order poles – Removable and essential singularities – Cauchy residue theorem and applications – Evaluation of real integrals using complex-valued functions involving sine and cosines – Integration using intended contours – Cauchy principal value – Integration along branch cuts – Introduction to conformal mapping.

UNIT IV: Integral Transforms (15 hours)

Fourier analysis – Half range Fourier series – Complex notation for Fourier series - Parseval's identity – Convergence of Fourier series and Gibb's phenomenon – Solving Laplace equation using Fourier series – Fourier integral representation of functions – Fourier integral theorem – Finite and infinite Fourier transforms – Fourier sine and cosine transforms – Complex Fourier transforms – Scaling, shifting and more properties of Fourier transforms – Convolution theorem – Parseval relation – Solving partial differential equations using Fourier transforms – Laplace transforms - Linearity property – First and second shifting theorems – Scaling theorem – Laplace transforms of derivatives versus Differentiation of Laplace transforms – Laplace transform of integrals versus Integration of Laplace transforms – Laplace transform of (b) unit step, and (c) Dirac delta functions – Filtering property of delta functions – Laplace transform of periodic functions – Convolution theorem and integrals – Solving initial value problems, differential equations, and integrodifferential equations.

Textbooks

[1] V Balakrishnan. Mathematical Physics. Springer.
[2] Jain and Iyengar, Advanced Engineering Mathematics, Narosa.
[3] Haberman, Applied Partial Differential Equations, Pearson.

Supplementary Readings

[1] Jeffrey, Advanced Engineering Mathematics, Academic Press.
[2] Zill and Shanahan, Complex Analysis, Jones and Bartlett Publishers.
[3] Spiegel, Advanced Calculus, Schaum Series, McGraw Hill.
[4] Spiegel, Fourier Analysis, Schaums Series, McGraw Hill.

PHYS 412 - CLASSICAL MECHANICS **(4 CREDITS / 1 TUTORIAL)**

Unit I **12 hours**

Mechanics of a system of particles – Conservation laws of linear and angular momenta for systems not subjected to external forces and torques – Constraints, degrees of freedom, generalized coordinates, and generalized potentials – Classification like holonomic, rheonomic, and scleronomous constraints - Virtual displacement and the principle of virtual work and D'Alembert's principle – Derivation of Lagrange equation from D'alembert's principle - Elements of the calculus of variations – Hamilton's least action principle - Lagrangian formulation - Derivation of Lagrange equations from Hamilton's principle - Applications to solve dynamical problems – Conservation theorems and symmetry properties – Norther's theorem.

Unit II **12 hours**

Motion in a central field – Kepler's problem – Reduction to equivalent one-body problem – Equation of motion for Kepler's problem and first integrals – Classification of orbits – Review of equations for circle, ellipse, parabola, and hyperbola in cartesian and polar coordinates – Transforming cartesian equation of ellipse to polar form – Differential equation for the orbit and power-law potentials – Bertrand theorem – The Laplace-Runge-Lenz vector – The concept of superintegrable systems – Scattering in a central field – Laboratory and center of mass frame – differential scattering cross section – scattering by a central field.

Unit III **12 hours**

Variational method – Legendre transformation and Hessian – Hamilton's equations – Cyclic coordinates and conservation theorems - Canonical transformations and applications – Generating functions – Infinitesimal contact transformations – Lagrange and Poisson brackets and canonical invariants – Angular momentum Poisson bracket relations – Hamilton-Jacobi theory with harmonic oscillator as an example.

Unit IV **12 hours**

Degrees of freedom of a rigid body and kinematic links – Orthogonal transformations - Rigid body rotation – Finite and infinitesimal rotation of rigid bodies - Laboratory and rotating frame of reference - Euler angles - Transformation between rotating and stationary frames – Coriolis and centrifugal forces – Angular momentum and kinetic energy about a point of rotating rigid body - Moment of inertia tensor and Principal axis transformation – Euler's equations – Symmetric top precession – Theory of small oscillations – Normal coordinates and forced oscillations.

Unit V **12 hours**

The special theory of relativity: Inertial frames – Lorentz transformations – Length contraction, Time dilation, and Doppler effect – Minkowski space – Index notation for vectors and tensors – Metric tensor – Einstein summation convection – Covariant and contravariant vectors - Energy momentum four vectors – Introduction to general relativity.

Textbooks

[1] Thornton and Marion. Classical Dynamics of Particles and Systems, Cengage Learning.
[2] Goldstein, Poole, Safko, Classical Mechanics, Addison Wesley.
[3] J C Upadhyaya. Classical Mechanics, Himalaya Publishing.
[4] P V Panat, Classical Mechanics, Narosa.
[5] David Morin, Special Relativity for the Beginner, CreateSpace Publishing.

Supplementary Reading

[1] David Morin, Classical Mechanics, Cambridge University Press.
[2] Synge and Griffith, Principles of Mechanics, McGraw Hill.
[3] Taylor, Classical Mechanics, University Science Books.
[4] Kibble and Berkshire. Classical Mechanics, Imperial College Press.
[5] Greenwood, Classical Dynamics, Prentice Hall.
[6] A K Raychaudri, Classical Mechanics, Oxford University Press.
[7] K G Gupta, Classical Mechanics of Particles and Rigid Bodies, Wiley.

PHYS 413 - QUANTUM MECHANICS - I **(4 CREDITS / 1 TUTORIAL)**

Unit – I **(12 hours)**
Review of Fourier transforms – Postulates of classical mechanics versus quantum mechanics - Dirac Bra and Ket notation – Expansion of vector in an orthonormal basis in Hilbert space – Matrix elements of linear operators – Adjoint of an operator – Unitary transformations – Eigenvalues and eigenvectors of complex Hermitian matrix – Simultaneous diagonalization of two Hermitian operators – Functions of operators: Calculation of exponential of an operator – Outer product and density matrix - Ehrenfest Theorem - Schrödinger picture – Heisenberg picture (matrix mechanics) – Interaction picture – Relation among different pictures – Commutator relations.

Unit – II **(12 hours)**
Solving the free particle problem in Dirac notation – Free particle propagator – Time evolution of the Gaussian packet – Continuity equation for probability current density - Definition of bound states and scattering states – Calculation of reflection and transmission coefficients for (a) Single-step potential, (b) Dirac-delta potential – Potential step – Infinite square well – Finite square well (or potential well) – Potential barrier and quantum tunneling effect – Discussion of degeneracy in the bound states in one-dimensional problems.

Unit – III **(12 hours)**
Taylor series expansion of potential – Quantum harmonic oscillator and normal modes – Solving the harmonic oscillator differential equation (Hermite polynomials) – Finding eigenfunctions and plotting – Calculation of energy eigenvalues – Solving the harmonic oscillator problem using operator method – Annihilation (lowering) and creation (raising) operators – Solution of a linear harmonic oscillator using (a) Schrödinger picture and (b) matrix mechanics – Matrix representation of harmonic oscillator operators – Schrodinger equation in the spherical coordinate system – Angular equation – Legendre polynomials and spherical harmonics – Radial equation – Spherical Bessel function and spherical Neumann function – Solution of hydrogen atom radial equation by power series method – Derivation of Bohr formula – Degeneracy of the hydrogen spectrum.

Unit – IV **(12 hours)**
Angular momentum in quantum mechanics – Angular momentum operator algebras – Ladder operators and the spectrum of eigenvalues – Commutation relations – Eigenvalues and Eigen functions of angular momentum operator – Matrix representation of angular momentum operators (basics concepts) – Spinor matrix and Pauli spin matrices – Addition (coupling) of angular momenta – Clebsch-Gordan coefficients.

Unit – V **(12 hours)**
Basics of discrete Symmetries – Symmetries, Conservation Laws, and degeneracy – Translational invariance – Time-translational invariance - Parity inversion (space inversion) – Time-reversal symmetry - Rotational Symmetry – Infinitesimal and Finite Rotations – Rotation Operator – Rotation Matrices – How operators transform under rotations? – Definition of scalar, vector, and tensor QM operators – Reducible and irreducible tensors and spherical tensors – Wigner-Eckart theorem.

Textbooks

[1] R Shankar, Principles of Quantum Mechanics, Springer.
[2] Liboff, Introductory Quantum Mechanics, Pearson Education.
[3] Ghatak and Lokanathan, Quantum Mechanics, Trinity Press.
[4] Griffiths, Introduction to Quantum Mechanics, Pearson Education.
[5] Zettili, Quantum Mechanics: Concepts and Applications, Wiley.

Supplementary Readings

[1] V Devanathan, Quantum Mechanics, Narosa Publishing House.
[2] Ashok Das, Lectures on Quantum Mechanics, World Scientific.
[3] Schiff, Quantum Mechanics, McGraw-Hill.

PHYS 414 - ELECTRONIC DEVICES AND CIRCUITS (4 CREDITS / 1 TUTORIAL)

Unit-I: Review of Semiconductor Physics 12 hours

Energy Bands in solids, Intrinsic and extrinsic Semiconductors, Transport phenomena in Semiconductors, Generation and recombination of charges, Diffusion, PN junction diode, Open-circuited p-n junction, p-n diode current, I-V characteristics using a diffusion model, Space-Charge Transition Capacitance, Diffusion Capacitance.

Unit-II: Semiconductor Diodes 12 hours

Zener diode: Operation, characteristics, equivalent circuits, and applications, Avalanche diode, Varactor diode and tuning circuits, Schottky diode, Tunnel diodes: Construction, operation, and V-I characteristics, characteristics of BJT, FET, and MOSFET, UJT: Operation, characteristics, UJT relaxation oscillator, BJT RC coupled amplifier and its frequency response.

Unit-III: Operational amplifiers 12 hours

Basics of differential amplifiers, operation and input modes of differential amplifiers, Characteristics of ideal and practical operational amplifier, Applications: inverting, non-inverting, voltage-follower, Summing, difference, integrating, differentiating amplifiers- Signal processing circuits: precision rectifiers, clipper, clamper, and peak detectors using operational amplifier.

Unit-IV: Signal generators and Active filters 12 hours

Signal generators and active filters - triangular and square wave generators, phase shift, and Wien bridge oscillator using operational amplifier - Active filters: First order low pass and high pass filters, Bandpass and band elimination filters using operational amplifier, Temperature compensated logarithmic and antilogarithmic amplifiers using operational amplifier.

Unit – V: Optoelectronics 12 hours

Radiative and nonradiative transition - Light-dependent resistor - Photodiodes, phototransistors, Photovoltaic solar cell materials - Construction and operation of the LED - Diode laser - Structure, working and factors affecting performance.

Textbooks

[1] Sze, Physics of Semiconductor Devices, Wiley.
[2] Boylsted and Nashelsky, Electronic Devices and Circuits, Pearson.
[3] Hawkes, Optoelectronics: An Introduction, PHI.
[4] Millman, Halkias and Pariksh, Integrated Electronics. McGraw Hill.

Suggested Readings

[1] Donald A. Neamen, Semiconductor Physics and Devices, McGraw Hill.
[2] Floyd, Electronic Devices, Pearson.
[3] V K Mehta and R Mehta, Principles of Electronics, S Chand.

PHYS 415 - SOLID STATE PHYSICS – I (4 CREDITS / 1 TUTORIAL)

UNIT – I: Crystal Structure and Symmetry 12 hours

Classification of solids according to symmetry – Translational symmetry – Bravais lattice – Unit cell – Simple, BCC and FCC lattices – Coordination number – Wigner-Seitz primitive unit cell and conventional unit cell – Crystal structure as a lattice with basis – Diamond structure – Examples of HCP and other closed packed structures – Sodium chloride, Cesium chloride and Zinc-blende structures – Reciprocal lattice – Volume of the reciprocal lattice – First Brillouin zone – Lattice planes – Miller indices of lattice planes – Crystal directions – Classification of Bravais lattices – Point symmetries – Reflection, inversion and rotation – Crystallographic point groups and nomenclature.

UNIT – II: Crystal Binding 12 hours

Classification of solids according to the distribution of valence electrons –Interatomic bonding – van der Waals bond – Covalent, molecular, and ionic crystals – Ionic radii – Mixed ionic and covalent solids – Examples – Metallic and hydrogen bonded solids – Cohesive energy – Lennard-Jones potential for molecular crystals Cohesion in ionic crystals – Madelung constant – Cohesion in covalent crystals and metals.

UNIT – III: Crystal Structure Analysis 12 hours

Braggs formulation of x-ray diffraction by crystal – von Laue formulation of x-ray diffraction by crystal – Application of different radiation (X-ray, electron, and neutron) for crystal structure determination – Experimental methods – Laue method – Rotating crystal method – Powder or Debye-Scherrer method – Calculation of geometrical structure factor for simple lattices such as BCC and Diamond – Basics of atomic form factor.

UNIT – IV: Lattice Dynamics and Thermal Properties 12 hours

Classical theory of harmonic crystal – Lattice potential energy – Harmonic approximation – Density of states of an elastic isotropic solid – Thermal energy of harmonic oscillator – Specific heat of classical crystal – Derivation of Dulong and Petit law – Normal modes of 1D monoatomic Bravais lattice – Normal modes of a 1D lattice with basis – Effects due to anharmonicity – Thermal expansion – Quantum theory of harmonic crystal – Normal modes versus Phonons – General form of lattice specific heat – High and low-temperature limits – Debye and Einstein models – Comparison of lattice and electronic specific heats.

UNIT – V: Electrical Properties of Metals 12 hours

Drude theory of metals – Calculation of relaxation times and DC electrical resistivity using Drude model – Hall effect in metals – Derivation of Hall coefficient using Drude model – Ground state properties of electron gas – Free electron gas in infinite square well potential – Fermi gas at absolute zero of temperature – Derivation of energy of Fermi gas at absolute zero – Sommerfeld theory of metals – Derivation of density of states and Fermi temperature of electron gas using the Sommerfeld theory – Failures of the free electron model.

Textbooks

[1] Wahab, Solid State Physics, Narosa Publishing.
[2] Ashcroft and Mermin. Solid State Physics. Holt-Saunders (Indian Edition).
[3] Dekker, Solid State Physics. MacMillan India Ltd, New Delhi.
[4] Kittel, Introduction to Solid State Physics. John Wiley (Indian Edition).

Supplementary Reading

[1] Blakemore. Solid State Physics. Cambridge University Press.
[2] Ibach and Luth. Solid State Physics. Springer (Indian Edition).

PHYS 421 – STATISTICAL PHYSICS – I (4 CREDITS / 1 TUTORIAL)

Unit - I: Statistical Methods 12 hours
Probability and statistics in real life - Random walk problem in one dimension – Calculation of probability for *n*-step movement in random walk (binomial distribution) – Derivation of mean value, dispersion, and higher moments for the random walk problem – Formal definitions for discrete and continuous random variables, probability distribution function (PDF) and probability density function (pdf) for (i) uniform, (ii) binomial, (iii) Poisson, and (iv) Gaussian distributions - Calculation of (a) expected values, (b) skewness, (c) kurtosis, (d) higher moments of statistical distributions – Central limit theorem – Law of large numbers – Random number generation – Properties of random numbers – Derivation of Stirling approximation for *N!* – Problems solving.

UNIT-II: Statistical Description of Physical Systems 12 hours
Specification of state of the system - Statistical ensemble – Finding microstates for spin ½ particles as example – Postulates of statistical mechanics – Interaction between macroscopic systems – Equilibrium conditions and constraints - Ergodic hypothesis – Distribution of energy between systems in equilibrium – Derivation of relation between the number of microstates and entropy - Phase space trajectory for a free particle and other physical systems - Phase space density - Liouville theorem – Calculation of ensemble averages – Calculation of thermodynamic quantities from statistical description – Problems solving.

UNIT-III: Microcanonical Ensemble 12 hours
Microcanonical ensemble (MCE)– Postulate of equal apriori probabilities – Number of microstates and relation to thermodynamic entropy – Boltzmann *H*-theorem and hypothesis – Gibbs paradox - Correct counting – Calculation of entropy of classical and quantum harmonic oscillator - Calculation of the number of microstates in the case of (a) an ideal gas, (b) crystalline solid: Dulong-Petit's law: Einstein's theory of specific heat and (c) Paramagnetism: Curie's law, Negative temperature, and Schottky anomaly in specific heat (d) Elasticity of a rubber – Problems solving.

Unit IV: Canonical Ensemble 12 hours
Canonical ensemble (CE) – Density of phase points in CE – Canonical partition function of an ideal monoatomic gas – Calculation of thermodynamic properties from partition function for (a) classical and quantum harmonic oscillators, (b) anharmonic oscillator, (c) thermal expansion of solids – Equipartition theorem and Virial theorem – Specific heat using CE - Application of canonical partition function to (a) Ideal gas (b) Crystalline solid (c) Black body radiation and Planck's theory (d) Theory of paramagnetism: Langevin and Brillouin functions (e) Diatomic molecular gas – Problems solving.

Unit V: Grand Canonical Ensemble 12 hours
Features of grand canonical ensemble (GCE)– Comparison of three types of ensembles – Density of phase points in GCE –Calculation of thermodynamic parameters using grand partition function for (a) ideal gas, (b) linear harmonic oscillator – Fugacity – Chemical potential of (i) classical ideal gas, (ii) ideal Fermi gas, (iii) ideal Bose gas, (iv) photon gas – Fluctuations in number density and fluctuation of energy – Saha's ionization potential - Application to (a) adsorption-desorption process, and (b) chemical reactions.

Textbooks

[1] Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill.
[2] Upendranath Nandi, Statistical Mechanics, Techno World.
[3] Pathria, Statistical Mechanics, Butterworth-Heinemann.

Supplementary Readings

[1] Reichl, A Modern Course in Statistical Physics, Wiley.
[2] Huang, Statistical Mechanics, Wiley.

PHYS 422 - CLASSICAL ELECTRODYNAMICS (4 CREDITS / 1 TUTORIAL)

UNIT – I: Special techniques in Electrostatics 15 hours

Laplace equation in cartesian, cylindrical, and spherical coordinates – The need for Dirac-delta function – Green functions – Derivation of divergence and curl of the electric field from Coulomb's law - Boundary conditions and uniqueness theorems — Conductors and second uniqueness theorem - Electrostatic potential problems in cartesian, cylindrical, and spherical coordinate systems – Method of images – Physical systems with and without azimuthal symmetry – Solutions using spherical harmonics - Dielectric polarization - Boundary value problems with linear dielectrics The field of a polarized object - Multipole expansion for scalar electric potential — Origin of coordinates in multipole expansions – Boundary conditions for the electric field across the interface between two dielectric media.

UNIT – II: Magnetostatics and Electrodynamics 15 hours

Lorentz force law and Biot-Savart law — Scalar and vector potentials — Derivation of divergence and curl of the magnetic field from Biot-Savart law - Multipole expansion of magnetic vector potential — Calculation of field inside matter - Amperes law in magnetized materials and Auxiliary field H — Boundary conditions for the magnetic field across the interface between two magnetic media - Faraday's law and Lenz's law — Calculation of energy density in magnetic fields — Electrodynamics before Maxwell — Maxwell's correction of Ampere's law — Continuity equation - Derivation of Maxwell's equations in vacuum and in matter.

UNIT – III: Electromagnetic waves 15 hours

Electromagnetic waves in vacuum — Wave equation for E and B fields — Reflection, refraction of electromagnetic waves — Snell's law and Fresnel's law — Poynting theorem and its derivation — Electromagnetic waves in matter — Propagation of electromagnetic waves in linear media — Reflection and transmission at normal and oblique incidence — Absorption and dispersion of electromagnetic waves — Electromagnetic waves in conductors — Reflection at a conducting surface — Interference, diffraction, and polarization.

UNIT – IV: Potentials and Radiation 15 hours

Potential formulation — Scalar and vector potentials - Gauge transformations — Coulomb and Lorentz gauge — Retarded potentials of continuous charge distribution — Derivation of Jefimenko's Equations - Retarded potentials of point charges - Lienard- Wiechert potential — Fields of a moving point charge — Electric dipole radiation — Energy radiated by an oscillating electric dipole — Radiation from moving charges — Radiation fields — Derivation of Larmor formula – Magnetism as a relativistic phenomenon – Electromagnetic field tensor - Relativistic formulation of Maxwell's equations – Covariant formulation of electrodynamics 0 Maxwell's equations in tensor notation.

Textbooks

[1] David J Griffiths, Introduction to electrodynamics, Prentice Hall.
[2] M N O Sadiku, Elements of Electromagnetics, Oxford University Press.

Supplementary Reading

[1] John David Jackson, Classical Electrodynamics, John Wiley.

PHYS 423: ATOMIC AND MOLECULAR PHYSICS (4 CREDITS / 1 TUTORIAL)

Unit I: 10 hours

Photoelectron spectroscopy: Introduction and processes related to photoelectron spectroscopy - X-ray photoelectron spectrometer - Ultraviolet photoelectron spectrometer – Chemical information from photoelectron spectroscopy – Solid state surface studies – Surface charging and calibration – Photoelectron intensities – Valence and core-energy level studies - Auger electron spectroscopy.

Unit II: 10 hours

Microwave Spectroscopy: Rotational spectra of rigid and non-rigid diatomic molecule - Isotope effect in Rotational Spectra- Intensity of Rotational Lines- Non-rigid Rotator Vibrational Excitation Effect-Linear Polyatomic molecules- Symmetric top molecules- Asymmetric top molecules – Stark effect-Quadrupole Hyperfine interaction – Microwave spectrometer – Information from Rotational spectra.

Unit III: 10 hours

Infrared Spectroscopy: Vibrational Energy of a diatomic molecule – The diatomic vibrating rotator – Break down of Born-Oppenheimer approximation – The vibrations of polyatomic molecules – Rotation-vibration spectra of polyatomic molecules – IR spectrophotometers - Applications – Electronic spectra of molecules - Frank-Condon principle and dissociation energy.

Unit IV: 10 hours

Raman spectroscopy: Raman effect – Understanding various scattering like (i) Rayleigh, (ii) Stokes, (iii) anti-Stokes, and (iv) Raman scattering – Polarizability to understand Raman effect – Maclaurin series expansion of polarizability – Polarizability ellipsoid Raman Spectroscopy: Theories of Raman scattering – Rotational Raman Spectra – Vibrational Raman Spectra – Mutual Exclusion principle – Raman Spectrometer – Polarisation of Raman Scattered light – Structural determination from Raman and IR spectroscopy - Near IR FT-Raman spectroscopy.

Unit V: 10 hours

Nuclear magnetic resonance spectroscopy: Basic principles – magnetic resonance – relaxation processes – Pulsed (Fourier Transform) NMR – Wide line NMR spectrometers – Molecular structure – Chemical shifts – Spin-spin coupling – Integration – Applications – Electron spin resonance spectroscopy: Basic principles – ESR spectrometer – ESR spectra – Hyperfine interaction – g-factor – line widths – applications.

Unit VI: 10 hours

NQR and Mossbauer Spectroscopy: Quadrupole Hamiltonian- Nuclear Quadrupole energy level for axial and non-axial symmetry – Experimental techniques and applications – Mossbauer Spectroscopy: Principles of Mossbauer spectroscopy – Chemical shifts – Quadrupole splitting and Zeeman splitting – applications of Mossbauer spectroscopy – applications.

Textbooks

[1] Straughan and Walker, Spectroscopy, 3-volume set, Science Paperbacks.
[2] J Michael Hollas, Modern Spectroscopy, Wiley.
[3] Banwell and McCash, Fundamentals of Molecular Spectroscopy, McGraw Hill.
[4] Aruldhas, Molecular Structure, and Spectroscopy, Prentice-Hall.
[5] Gupta, Kumar, Sharma, Elements of Spectroscopy: *Atomic, Molecular and Laser Physics*, Pragati Prakashan.

Supplementary Readings

[1] H. E. White, Introduction to Atomic Spectra. McGraw Hill.
[2] G Herzberg, Atomic Spectra and Atomic Structure, Dover.
[3] D. A. Long, Raman Spectroscopy.
[4] Tores and Schawlow, Microwave Spectroscopy. McGraw Hill.
[5] Schneider and Berstin, High-Resolution NMR. McGraw Hill.
[6] Assenheim, Introduction to ESR. Plenum Press.
[7] Das and Hahn, Nuclear Quadrupole Resonance Spectroscopy. Academic Press.
[8] Goldanskil, Mossbauer effect and its application to Chemistry. Von Nostrand.

PHYS 424 –MATHEMATICAL PHYSICS – II (4 CREDITS / 1 TUTORIAL)

Unit-I: Linear Algebra (15 hours)

Introduction to abstract algebra and notation – Definition of groups, real fields, and complex fields Definition of vector space – Vector spaces over an arbitrary field - Linear vector spaces and subspaces – Null space - Span and independence of vector space – Spanning set theorem - Linear dependence and independence – Dimensionality of vector space - Basis sets for finite dimensional and infinite dimensional vector spaces – Linear transformation (mapping) - Norm and Inner product – Unit circles and spheres in inner product spaces - Cauchy-Schwarz Inequality – Orthogonal and orthonormal sets and bases - Completeness – Eigenvalues and Eigenvectors - Matrix representation - Change of orthonormal basis.

Unit-II: Hilbert Spaces and Operators (15 hours)

Definition of metric space and normed spaces – Definition of linear functional – Inner product spaces - Hilbert space – Families of orthogonal polynomials as basis sets in function space (Gram-Schmidt orthogonalization) – Self-adjoint and Normal operators – Linear operators – Hermitian, unitary, orthogonal, and projection operators – Trace, inverse, and rank of a linear operator - Rotation matrices in two and three dimensions – Pauli matrices.

Unit-III: Vectors and Tensors in Index Notation (15 hours)

Representation of vectors and matrices in index notation – Einstien summation convention - Dot product, cross product, scalar triple product, and vector triple product using index notation – Vector identities and differential operators in curvilinear coordinates and compact notation using indices – Evaluation of determinant of a matrix using Levi-Civita symbol - Fundamentals of tensors – Cartesian Tensors – Algebra of cartesian tensors – Outer product – Contraction - Quotient theorem – Symmetric and Skew-symmetric tensors – Kronecker and Levi-Civita tensors – Examples and Applications in physics.

Unit-IV: Group Theory (15 hours)

Introduction to Groups, fields - Definitions and examples of physically important finite groups - Point groups - Multiplication table – Subgroups - Cyclic groups, center, classes, cosets, Lagrange Theorem - Representations of finite groups - Irreducible representation – Characters - Orthogonality theorem - Schur's character table - SU(2) – SU(3) – Simple applications.

Textbooks

[1] V Balakrishnan, Mathematical Physics: Applications and Problems. Springer.
[2] Byron and Fuller. Mathematics of Classical and Quantum Physics. Dover.
[3] B R Kusse and E A Westwig. Mathematical Physics. Wiley-VCH.
[4] Kreyszig. Introductory Functional Analysis with Applications. Wiley.

Supplementary Readings

[1] Riley, Hobson, and Bence. Mathematical Methods for Physics and Engineering, Wiley.
[2] S Fujita and S V Godoy. Mathematical Physics. Wiley.
[3] Arfken et al., Mathematical Methods for Physicists. Elsevier.
[4] S Hassani. Mathematical Physics. Springer International Publishing.

PHYS 425 - SOLID STATE PHYSICS - II (4 CREDITS / 1 TUTORIAL)

UNIT – I: Band Theory of solids 12 hours

Electron levels in a periodic potential – Bloch's theorem – von Karman boundary condition – Fermi surface and density of states – Kronig-Penny model – Electrons in a weak periodic potential – Energy bands in one dimension – Formation of energy gap – General formulation for determination of band structure – Tight binding method – Experimental methods to study band structure.

UNIT – II: Semiconductors 12 hours

Band structure of a typical semiconductor – Direct and indirect band-gap semiconductors – Derivation of number of carriers in thermal equilibrium for the intrinsic semiconductor – Doping in semiconductors – Population of impurity levels in thermal equilibrium – Derivation of carrier densities in doped semiconductors – Conductivity in semiconductors – Temperature dependence – Hall effect in semiconductors – Derivation of Hall coefficient.

UNIT – III: Dielectric Properties 12 hours

Maxwell's equations for dielectrics – Local field theory for insulators – Derivation of Clausius-Mossotti relation – Theory of polarizability – Derivation of expression for atomic polarizability and displacement polarizability – Frequency dependence of dielectric polarizability – Application of ionic crystals to optical properties –Pyroelectricity and Ferroelectricity.

UNIT – IV: Magnetic Properties 12 hours

Interaction of solids with magnetic fields – Magnetization and Susceptibility – Calculation of atomic susceptibilities – Larmor diamagnetism – Derivation of diamagnetic susceptibility of insulators– Derivation of paramagnetic susceptibility of free ions – Curie law– Brillouin function – Susceptibility of metals – Derivation of Pauli paramagnetic susceptibility – Landau diamagnetism –Magnetic ordering and magnetic structure – Classification of solids into ferro, ferri and anti-ferro magnets – Curie and Neil temperatures – Domain theory for ferromagnetism – Basics of spin waves and magnons.

UNIT – V: Superconductors 12 hours

History of the discovery of superconductivity – Critical temperature – Persistent currents – Difference between perfect (ideal) conductor and superconductor – Perfect diamagnetism – Meissner effect – Destruction of superconductivity by magnetic fields – Critical field – Derivation of London equation – Isotope effect – Elementary BCS theory – Coherence length – Specific heat capacity and energy gap of superconductors Type-I and Type-II superconductors – Basics of high-temperature superconductors – Supercurrent tunneling – Qualitative treatment of DC and AC Josephson effect.

Textbooks

[1] Wahab, Solid State Physics, Narosa.
[2] Ashcroft and Mermin. Solid State Physics. Holt-Saunders (Indian Edition).
[3] Dekker, Solid State Physics. MacMillan. (Indian Edition).
[4] Kittel, Introduction to Solid State Physics. John Wiley (Indian Edition).

Supplementary Reading

[1] Blakemore. Solid State Physics. Cambridge University Press.
[2] Ibach and Luth. Solid State Physics. Springer (Indian Edition).

PHYS 426 – NONLINEAR OPTICS **(4 CREDITS / 1 TUTORIAL)**

Unit I **12 hours**

Maxwell Equations - Wave Equations in various media and its propagation (Brief Survey) - Origin of Complex Refractive Index - Classical theory of Optical Absorption (Electron Oscillator Model) and Dispersion (Lorentz Oscillator Model) - Classical theory of anharmonic oscillators.

Unit II **12 hours**

Wave equations description of nonlinear optical susceptibilities – Symmetries in Nonlinear Optical Systems - Frequency and intensity dependence of polarization and dielectric susceptibility - First-order and higher-order susceptibilities.

Unit III **12 hours**

Second-order optical nonlinearities - Second harmonic generation – Sum and difference frequency generation - Parametric processes – Simple theory and calculation of nonlinear polarization – Various phase matching techniques in SHG.

Unit IV **12 hours**

Third order optical nonlinearities - Third harmonic generation - Four-wave mixing, Kerr Nonlinearity - Intensity dependent effect - Self-Phase modulation - Cross phase modulation - Stimulated Raman Scattering (SRS) - Stimulated Brillouin scattering - Parametric gain – Parametric amplification and oscillation.

Unit V **12 hours**

Electro-Optic Effect- based on changes in Index ellipsoid -Pockel and Kerr Effect, Applications as Modulators and Phase Retarders. Optical Phase Conjugation Theory and Applications, Photorefractive effect and applications, Solitons Theory and applications – Optical bistability.

Textbooks

[1] Robert W Boyd, Nonlinear Optics.
[2] Y Guo, C K Kao, E.H.Li, K. S.Chiang, Nonlinear Photonics.
[3] Y R Shen, Principles of Nonlinear Optics.
[4] N. Bloembergen, Nonlinear Optics.

Supplementary Readings

[1] Amnon Yariv, Quantum Electronics.
[2] Saleh and Teich, Fundamentals of Photonics, Wiley.
[3] Duarte, Tunable Laser applications, CRC press.
[4] Robert R. Alfano, The Supercontinuum Laser Source, Springer.
[5] P. Hariharan, Optical Holography, Cambridge University Press.
[6] Joseph Rosen, Holography: Research and Technologies, InTech.
[7] U. Schnars and W. Jueptner, Digital Holography, Springer.
[8] Ghatak and Thyagarajan, An Introduction to fiber optics, Cambridge University Press.
[9] John Crisp and Barry Elliot, Introduction to fiber optics, Elsevier.
[10] G P Agrawal, Nonlinear Fiber optics, Elsevier.
[11] G Keiser, Optical fiber communications, Fourth edition, Tata McGraw Hill.
[12] G P Agrawal, Fiber optics communication, Wiley.
[13] H S Nalwa and S Miyata, Nonlinear Optics of Organic Molecules and Polymers.
[14] RA Fischer, Optical Phase Conjugation.
[15] R Sutherland, Handbook of Nonlinear Optics.
[16] N B Singh, Growth and Characterization of Nonlinear Optical Materials.

PART – IX

DETAILED SYLLABUS

OF

MINOR PAPERS

(Offered by the Physics Department)

(for Mathematics / Chemistry / other Science students)

MINOR PAPER - 1

PHYS 117 - CONCEPTS IN MECHANICS (4 CREDITS / 1 TUTORIAL)

UNIT – I 12 hours

Scalar and vector fields – Gradient of a scalar field and its physical significance – Divergence and Curl of a vector field and their physical importance - Vector integrations: Line, surface, and volume integrals – Stokes theorem – Gauss divergence theorem - Greens theorem on the plane – Problems solving.

UNIT – II 12 hours

Resolving a force in two perpendicular directions – Addition of forces - Polygon of forces - Condition for the equilibrium of a particle under several forces – Lami's theorem and problems based on it - Forces along and perpendicular to the inclined plane - Limiting equilibrium (about to slide) of a particle kept on an inclined plane – Friction laws (static and dynamic) – Calculation of acceleration of sliding objects down an inclined plane – Moment of a force – Conditions for the equilibrium of a rigid body – Resultant of forces – Three parallel forces acting at the vertices of a triangle – Three forces acting along the sides of a triangle – Defining couple and moment of a couple – Resultant of several coplanar forces – Equilibrium of a rigid body under coplanar forces.

UNIT – III 12 hours

Defining center of mass - Calculation of the center of mass of geometrical objects like (i) arc of a circle, (ii) rectangle with a cavity, (iii) triangle, (iv) solid hemisphere, (v) solid cone, (vi) circular plate having a circular hole – Defining moment of inertia – Parallel and perpendicular axes theorems - Calculation of moments of inertia of (i) a circular ring, (ii) circular lamina, (iii) solid sphere, (iv) spherical shell, (v) solid cone.

UNIT – IV 12 hours

Definition of impulsive force and application to collision problems – Newton's laws of collision – Coefficient of restitution – Line of impact – Collision of two smooth bodies – Conservation of momentum in collisions - Direct impact of two spheres - Loss of kinetic energy by direct impact - Oblique impact of two spheres - Loss of kinetic energy by oblique impact - Calculation of coefficient of restitution – Analytical problems solving.

UNIT – V 12 hours

Moduli of elasticity and Poisson ratio – Derivation of the relation between elastic constants - Bending of beams and Cantilever problems - Torsion in a string and torsional pendulum – Calculation of couple per unit twist of a cylinder (torsional rigidity) – Bending of beams: Bending moment and couple – Calculation of bending due to uniformly distributed load – Calculation of depression of supported beams due to weight – Newton's law of viscosity - Kinematic and dynamic viscosity Poiseuille's formula for the flow of liquid through a capillary tube - Streamline and turbulent flows – Archimedes principle - Equation of continuity - Bernoulli theorem – Euler's equation – Reynolds number and its applications – Motion of a body in a viscous medium.

Textbooks

[1] Duraipandian and Jayapragasam, Mechanics, S Chand.
[2] Halliday, Resnick Walker, Fundamentals of Physics, Wiley.
[3] D S Mathur, Elements of Properties of Matter, S Chand.

Supplementary Readings

[1] Susan Jane Colley, Vector Calculus, Pearson.
[2] A P French, Newtonian Mechanics, MIT Series, Norton Publishers.
[3] David Morin, Classical Mechanics, Cambridge University Press.
[4] D S Mathur, Mechanics, S Chand.

MINOR PAPER - 2

PHYS 127 – CONCEPTS IN THERMODYNAMICS (4 CREDITS / 1 TUTORIAL)

Unit – I (12 hours)

Functions of several variables - Partial derivatives – Euler theorem – Chain rule – Exact differentials Classification of differential equations – First order differential equations – Method of integrating factor of the exact differential equation – Method of separation of variables – Second order differential equation – Solution of homogeneous equations – Applications of first and second order differential equations to physical systems - Problems solving.

Unit – II (12 hours)

Extensive and intensive variables - Thermodynamic equilibrium - Zeroth law - State functions - Relations between partial derivatives – Exact differentials – Internal energy function - Differential form of first law and applications - Quasi-static processes - Relation between heat capacities CP and CV - Work done during isothermal and adiabatic processes - Compressibility and expansion coefficients - Second law - Reversible and irreversible processes with examples - Heat engines - Carnot cycle – Problems solving.

Unit – III (12 hours)

Entropy - Clausius theorem - Clausius inequality - Second law in terms of entropy - Entropy of a perfect gas - Principle of increase of entropy - Entropy changes in reversible and irreversible processes with examples –Entropy of the Universe - Temperature-entropy (TS) diagrams for thermodynamic cycles - Third law of thermodynamics - Unattainability of absolute zero – Problems solving.

Unit – IV (12 hours)

Thermodynamic potentials - Internal Energy – Enthalpy - Helmholtz free energy - Gibb's free energy - Properties and applications – Relation between partial derivatives – Phase transitions with examples – Clausius-Clapeyron equation – Heat capacities at constant pressure and constant volume – TdS equation - Change in temperature during the adiabatic process - Free adiabatic expansion of a perfect gas – Problems solving.

Unit – V (12 hours)

Kinetic theory of gases - Distribution of velocities - Mean, RMS, and most probable speeds - Behavior of real gases - Deviations from the ideal gas equation - Andrew's experiments on carbon dioxide – Van der Waal's equation of state for real gases - Law of corresponding states – Problems solving.

Textbooks

[1] Boyce and Diprima, Differential Equations, Wiley.
[2] Zemansky and Dittman. Heat and Thermodynamics, McGraw-Hill.
[3] Halliday, Resnick Walker, Fundamentals of Physics, Wiley.

Supplementary Readings

[1] Spiegel, Advanced Calculus, Schaum Series, McGraw Hill.
[2] Sears and Salinger. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Narosa.
[3] L. B. Leob, Kinetic theory of gases, Dover.
[4] Carl S. Helrich, Modern Thermodynamics with Statistical Mechanics, Springer.
[5] D S Mathur, Heat and Thermodynamics, S Chand.
[6] Brijlal and Subramaniam, Heat and Thermodynamics, S chand.

MINOR PAPER - 3 (LABORATORY TRAINING)

PHYS 217 – MINOR PHYSICS LABORATORY – I **(3 CREDITS LAB)**

Choose any seven experiments from the list.

1. Find the least count of screw gauge and vernier caliper.
2. Simple pendulum.
3. Moment of inertia of flywheel.
4. Bar pendulum.
5. Study of the moment of a couple.
6. Torsion pendulum
7. Kater's pendulum.
8. Linear air track.
9. Study of gyroscope.
10. Inclined plane analysis.
11. Bifilar pendulum.
12. Free fall study.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith. Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

MINOR PAPER - 4 (LABORATORY TRAINING)

PHYS 227 – MINOR PHYSICS LAB – II (3 CREDITS LAB)

(Choose any seven experiments from the list)

1. Thermal conduction of poor conductor.
2. Study of thermocouple.
3. Specific heat by the method of cooling.
4. Joule's calorimeter.
5. Latent heat of fusion of ice by the method of mixtures.
6. Specific heat of bad conductor.
7. Specific heat of liquid using ice.
8. Determination of Stefan constant.
9. Study of the Boltzmann curve.
10. Thermal conductivity of glass.
11. Study of cooling curve.
12. Forbe's method for good conductor.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith, Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

MINOR PAPER - 5 (LABORATORY TRAINING)

PHYS 317 – MINOR PHYSICS LAB – III **(3 CREDITS LAB)**

Choose any seven experiments from the list.

1. Nonlinear torsion by weights
2. Frequency of tuning fork by sonometer.
3. Melde's string.
4. Calibration of ammeter using potentiometer.
5. Calibration of voltmeter using potentiometer.
6. Study of vibration magnetometer.
7. Surface tension by capillary rise.
8. Surface tension by method of drops.
9. Viscosity of liquids by Poiseuille's method.
10. Comparison of viscosities of two liquids by capillary flow method.
11. Determination of Young's modulus by non-uniform bending using a single optic lever.
12. Determination of rigidity modulus by static torsion method.
13. Wheatstone's bridge.
14. The specific resistance of a metal wire by meter bridge.
15. Determination of unknown resistance by Carey-Foster bridge.
16. Resistance measurement by ballistic galvanometer.
17. Figure of merit of a ballistic galvanometer.
18. Comparison of resistances using a ballistic galvanometer.

Text Books

[1] H. Singh, B.Sc., Practical Physics, S. Chand.
[2] Srinivasan and Balakrishnan, A Textbook of Practical Physics. Viswanathan Publishers.

Supplementary Reading

[1] Samir Kumar Ghosh, A Textbook of Practical Physics, New Central Book Ltd.
[2] B. Ghosh, Advanced Practical Physics. Sreedhar Publishers.
[3] Smith, Manual of Experiments in Applied Physics. Butterworth.
[4] Workshop and Flint. Advanced Practical Physics for Students, Methuen and Co.
[5] Jerrad and Neil, Theoretical and Experimental Physics.

MINOR PAPER - 6

PHYS 327 - CONCEPTS IN ELECTROMAGNETISM (4 CREDITS / 1 TUTORIAL)

Unit – I (12 hours)

Coulomb's law – Electric flux and flux density – Discrete and continuous charge distributions - Defining linear, surface, and volume charge density - Electric field due to discrete and continuous charge distributions – Calculation of electric field due to the following: an infinitely long line charge, a sheet of charge, a ring of charge, a charged disk – Electric field due to an electric dipole – Gauss's law – Applications of Gauss's law for the following: Point charge, Infinite line charge, Infinite sheet of charge, Uniformly charged sphere (solid and shell) and cylinder – Electric dipole in an electric field – Torque – Motion of point charges in electric fields – Problems solving.

Unit – II (12 hours)

Work and energy in electrostatic systems – Electric potential – Definition of potential difference and potential – Calculating the potential from the field and vice-versa – Potential inside and outside of a spherical shell of charge – Equipotential lines and surfaces – Energy expended in moving a point charge in an electric field – Calculation of electric potential due to a system of discrete charges and continuous charge distributions – Potential gradient – Derivation of energy density in an electrostatic field – Potential energy of an electric dipole in an electric field – Calculation of energy density due to symmetric charge distributions – Problems solving.

Unit – III (12 hours)

Convection and conduction currents – Derivation of Ohms law $J = \sigma E$ – Derivation of resistivity, resistance, and power in a current carrying conductor – Nature of dielectric materials – Definition of electric polarization – Dielectric breakdown – Capacitors – Calculating the capacitance of a parallel plate capacitor, a cylindrical capacitor, a spherical capacitor, coaxial cylindrical capacitor, concentric spherical capacitor and for an isolated spherical capacitor – Capacitor with a dielectric – Gauss's law in the presence of linear dielectrics – RC and LCR circuits – Solving series-parallel combinations of circuits containing resistors, capacitors, and inductors – Kirchhoff's laws - Problems solving.

Unit – IV (12 hours)

Magnetic fields and related SI units – Biot-Savart's law – Lorentz force equation – Dynamics of charged particles in magnetic fields – Circulating helical path of electrons – Magnetic force on a current carrying wire – Torque on a current loop – Magnetic dipole moment of a magnetic dipole – Calculation of magnetic field due to (i) a long straight wire, (ii) a circular arc of wire, (iii) a solenoid and for other simple current configurations– Force between two parallel currents –

Unit – V (12 hours)

Ampere's law – Applications of Ampere's law to calculate magnetic field due to following symmetric current distributions: a long straight current carrying wire, a solenoid, and toroid – Equivalence of current carrying loop and a magnetic dipole – Faraday's law of induction – Lenz's law – Induction and energy transfers – Motional e.m.f – Eddy currents – Inductance of a solenoid – Self-induction of a coil – Mutual induction – Energy stored in a magnetic field – Calculation of magnetic energy density – Problems solving.

Textbooks

[1] Resnick and Halliday, Fundamentals of Physics, Wiley.
[2] Edward M. Purcell. Electricity and Magnetism. McGraw-Hill.

Supplementary Readings

[1] Knight, Physics for Scientists and Engineers, Pearson.
[2] Kraus and Carver, Electromagnetics, McGraw-Hill.

MINOR PAPER - 7

PHYS 417 – CONCEPTS IN MATERIALS SCIENCE (4 CREDITS / 1 TUTORIAL)

Unit – I: Phase Rule (12 hours)

Classification of crystalline and amorphous materials - Structure-property relationships – Solubility limit and microstructure - Stability and meta stability - Thermodynamic functions and kinetics of phase transformations - Phase diagrams, Gibb's phase rule - Lever rule - One and two-component solid solutions – Eutectic systems - Microstructural changes during cooling – Examples of binary phase diagrams.

Unit – II: Crystal Structure (12 hours)

Crystals – Classification of crystal systems – Introduction to Bravais lattice – Calculation of distance between crystal planes – Miller indices – Calculation of linear, planar, and volume densities – Packing fraction – Ionic crystals, covalent crystals - Van der wall, metallic and dipole bonding - Single crystals - Techniques of growing single crystals like melt growth – Basics of thin films – X-ray sources and diffraction.

Unit – III: Defects and Diffusion (12 hours)

Impurities in solids – Vacancies and interstitials - Point and line defects – Edge and screw dislocations – Planar defects and grain boundaries - Elastic deformation – Critical shear stress – Effect of lattice defects on mechanical properties – Stress-strain curve – Yield stress - Young's modulus, Poisson ratio and hardness of materials.

Unit – IV: Electrical Properties (12 hours)

Origin of band gap in solids – Classification of metals, insulators, and semiconductors – Electron mobility – Derivation of electrical conductivity of metals based on Drude theory – Drift velocity of electrons in metals – Forbidden gap – Semiconductor materials (Ge, Si, GaAs) - Effect of temperature on semi-conductivity.

Unit – V: Magnetic Properties (12 hours)

Definition of Bohr magneton - Magnetic moment of electrons – Classification as dia, para, and ferromagnetic materials – Curie-Weiss law – Molecular field theory of ferromagnetism – Temperature dependence of magnetic susceptibility – Examples with their crystal structures (like cubic ferrites).

Textbooks

[1] Raghavan, Materials Science and Engineering, Prentice Hall.
[2] Callister and Rethwisch. Materials Science and Engineering, Wiley.
[3] Hummel, Electronic Properties of Materials, Springer.
[4] Cullity and Graham, Introduction to Magnetic Materials, Wiley.
[5] Blackmore, Solid State Physics, Cambridge University Press.

Supplementary Readings

[1] Moffatt, Pearsall, and Wulff, Structure and Properties of Materials, 4-volume set, Wiley.
[2] Smith and Hashemi. Foundations of Materials Science and Engineering. McGraw-Hill
[3] Saka. Introduction to Phase Diagrams in Materials Science. World Scientific.
[4] Askeland and Wright. The Science and Engineering of Materials. Cengage Learning.

MINOR PAPER - 8

PHYS 427 – CONCEPTS IN PLASMA PHYSICS (4 CREDITS / 1 TUTORIAL)

Unit – I (12 hours)

Breakdown mechanism of gases, Definition of plasma, Electron current flow in a vacuum tube, Thermal distribution of velocities in a plasma, Debye shielding, Characteristic of DC glow discharge and DC arc discharge, Thermal and non-thermal plasma, basic diagnostic tools.

Unit – II (12 hours)

Fluid equations for plasma, Relation between fluid equations and guiding-center drifts, Single-fluid magneto-hydrodynamics, Particle drifts in uniform fields, Particle drifts in non-uniform magnetic fields, Particle drifts in time-dependent fields.

Unit – III (12 hours)

Fully and partially ionized plasmas, Collisions in fully ionized plasmas, Diffusion in plasmas, Elementary Charged Particles in Plasma and Their Elastic and Inelastic Collisions, Ionization Processes, Mechanisms of Electron Losses: Electron-Ion Recombination, Formation of Negative Ions, Ion-Ion Recombination Processes, Ion-Molecular Reactions.

Unit – IV (12 hours)

AC and DC discharges, RF discharges, Inductive discharges, power transfer efficiency, matching network, electron-cyclotron resonance discharges, helicon- discharges, surface wave discharges, DBD discharges, hollow cathode discharge, planer magnetron discharge.

Unit – V (12 hours)

Natural and Manmade Plasmas, Plasmas in Industry, Plasma Applications for Environmental Control, Plasma Applications in Energy Conversion, Plasma Application for Material Processing, Plasma etching, plasma nitriding, thin film formation, PECVD for nano-material fabrication

Textbooks

[1] Chapman, Brian N. Glow discharge processes, Wiley-Interscience.
[2] Lieberman and Lichtenberg, Principles of Plasma Discharges and Material Processing, Wiley.
[3] Goldston and Rutherford, Introduction to Plasma Physics, IOP Publishing.

Supplementary Readings

[1] P. I. John, Plasma Science and the Creation of Wealth, Tata McGrow-Hill.
[2] F.F. Chen, Introduction to Plasma Physics and Controlled Fusion, Springer.
[3] Alexander Piel, Plasma Physics, Springer.

PART – X

DETAILED SYLLABUS

OF

MULTI-DISCIPLINARY PAPERS

(Offered by the Physics Department)

(for Arts / Commerce / Social Sciences / Humanities students)

MULTI-DISCIPLINARY PAPER - 1

PHYS 115 - SCIENCE AND SOCIETY (3 CREDITS / 45 HOURS)

Unit – I (9 hours)

Manhattan project and definition of Modern and Ancient science in words of Prof. J. R. Oppenheimer. The first science Texts. The first theory of evolution and the 1st use of mathematics to measure the universe, nature, culture, and science.

Unit – II (9 hours)

The birth of scientific methods refutation of ancient authorities through observation and experimentation. Instruments and new concepts, Rules of reasoning

Unit – III (9 hours)

The laws of new science, two different theories of earth's present form, Unanswered questions-calculating the age of the earth, Continental drift

Unit – IV (9 hours)

The first systematic attempt to describe the history of life, the origin of species, the laws of heredity, cell-level discoveries, mysteries of inheritance, Darwinist reductionism, relativity, quantum jumps, the big-bang, butterfly effect

Unit – V (9 hours)

Distinction between heat and temperature – Evolution of temperature measurements – Kelvin's absolute temperature – Concept of triple point of water – Three laws of thermodynamics.

Textbooks

[1] Story of Science From writings of Aristotle to the Big Bang Theory by Susan Wise Bauer, W.W. Norton and Company, 2015.

Supplementary Readings

[1] Tantra Sangrah of Nilakantha Somayaji by K Ramaswamy and M S Sriram, Hindustan Book Agency, 2011.
[2] Hindu Astronomy by W. Brennand, (Caxton Publication India, 1998).
[3] Indian Astronomy: Concepts and Procedure by Dr. S. Balachandra Rao.
[4] Origin of Life by Freeman Dyson, (Cambridge University Press

MULTI-DISCIPLINARY PAPER - 2

PHYS 125 – PHYSICS OF ENERGY AND MATERIALS (3 CREDITS / 45 HOURS)

UNIT - I **11 hours**

Understanding the scope of Science, Engineering, and Technology. Scope of Physics, how it is different from Chemical Sciences, Life Sciences, Social science etc., the need for science in society, and the Correlation between scientific discovery and the advancement of technology.

UNIT - II **11 hours**

Definition of Energy, Role of Energy for life on earth, Energy needs for human civilization, Different types of energy resources, Present global / national / state-wise energy demand and supply and shortage, Expected energy demand for India in 2050 - How international relations depend on Energy.

UNIT – III **12 hours**

Materials around us and classification of materials depending on use and their physical properties. Different techniques to characterize materials (XRD, FTIR, NMR etc), physical and chemical properties, need of new materials (for aircraft, for body implants, for buildings), and techniques to fabricate new materials.

UNIT – IV **11 hours**

Pollution and economic growth, Conflicts for energy resources, different types of pollution and need for sustainable development, green energy resources, and green materials for sustainable development.

Text Books

[1] Raymond A. Serway, Physics for Scientists and Engineers with Modern Physics.
[2] K. V. Sharma, P. Venkataseshaiah, Energy management and conservation.
[3] V Raghavan, Materials Science and Engineering. PHI

Suggested Readings

[1] https://sdgs.un.org/goals Department of Economic and Social Affairs Sustainable Development.

MULTI-DISCIPLINARY PAPER - 3

PHYS 215 - ASTRONOMY FOR BEGINNERS (3 CREDITS / 45 HOURS)

Unit I – Astronomy by Naked Eyes 9 hours

Astronomy – How it influences everyday life - Ancient astronomy of different civilizations. Classification of different celestial bodies, events, and Constellations from past to present - Understating the motion of celestial bodies from geocentric to the heliocentric universe to the present-day universe - Positional astronomy- Evolution of different coordinates systems and their role in understanding the motion of celestial bodies.

Unit 2 Large Scale Structure of Universe 9 hours

Different types of Celestial Bodies- Asteroids, Meteors, Comets, Moon, Planets in the Solar System and their Satellites, Stars and their Binaries -Different Types - Neutron Stars, White and Brown Dwarfs - Cosmology Large scale structure of Universe- Galaxies, Clusters of Galaxies, Black Holes, Quasars, Blazars, Different theories of origin of Universe- Big Bang and Inflationary Model

Unit 3 Observational Astronomy 9 hours

The electromagnetic spectrum, Astronomical Scales – Astronomical Distance –Measuring distance of different objects from the Moon to Planets, Sun, Nearby Stars, Galaxy and estimate the size of the universe. Brightness of Stars, Classification of Stars based on the brightness – Luminosity - The apparent luminosity of stars – H-R Diagram.

Unit 4 Life of Stars 9 hours

Sun and its structure - Nuclear reactions in the sun – Photosphere – Chromosphere – The corona – solar prominence – solar flares - The temperature of the sun – solar wind, Stellar Evolution-Chandrasekhar Limit

Unit 5 Fundamentals of Astronomy 9 hours

Tools of astronomy, Optical Telescopes – Radio Telescopes – The Hubble Space Telescope (HST) – James Webb Space Telescope - Telescopes and their design, present space-based/ground-based observatories.

Text Books

[1] B Basu, An introduction to Astrophysics, PHI.
[2] K S Krishnasamy, Astrophysics. New Age.
[3] Frank H Shu. The Physical Universe: An Introduction to Astronomy. University Science Books.

Suggested Readings

[1] Baker and Fredrick, Astronomy, Van Nostrand.
[2] V B Bhatia. Textbook of Astronomy and Astrophysics. Narosa.
[3] B W Carroll & D.A. Ostlie, Modern Astrophysics, Addison-Wesley.
[4] M Zeilik and S.A. Gregory, Introductory Astronomy and Astrophysics, Saunders.
[5] S Kumaravelu, Astronomy, Janki Calendar Corporation.
[6] Hewish. A, Physics of the universe, CSIR publication, New Delhi.
[7] Biman Basu, Inside Stars, CSIR Publication, New Delhi.
[8] Biman Basu, Cosmic Vistas, National Book Trust of India.
[9] W K Hartmann, The Cosmic Voyage through Time and Space. Wadsworth Publishing.

MULTI-DISCIPLINARY PAPER – 4

PHYS – 225 – PHYSICS OF THE ENVIRONMENT (3 CREDITS / 45 HOURS)

UNIT-I - INTRODUCTION (12 Hrs)

Scope of environmental physics: Importance of Energy; Types of energy (mechanical, heat, chemical, nuclear, electrical). Law of conservation of energy. Energy transformations. Mechanical energy: force, work, kinetic and potential energy, conservation of mechanical energy, chemical energy. Energy in biology, photosynthesis, respiration. Energy use in the human body, energy content of food, Laws of thermodynamics.

UNIT-II - ATMOSPHERE (11 Hrs)

Structure and composition of the atmosphere: Residence time, Atmospheric aerosols; Atmospheric pressure, Physical processes and phenomena operating in the atmosphere and oceans; Dynamics in climate systems, Motion of air and water, mathematics of wave propagation; Air masses and weather fronts; Principal forces acting on air masses, pressure gradients, and winds; global convection, global wind patterns; cyclones and anti-cyclones.

UNIT-III - HEAT TRANSFER (11 Hrs)

Internal Energy, Specific Heat. Ideal gas equation. Kinetic theory, Interpretation of pressure and temperature. Work, heat, atmospheric lapse rate, and adiabatic lapse rate. Radiant energy, radioactive decay, radiant energy transport, Blackbody radiation, Earth as a blackbody, understanding the greenhouse effect using energy balance models, global warming. Physics of soil: soil and hydrologic cycles, surface tension, soil temperature.

UNIT-IV - DISPERSION OF POLLUTANTS (11 Hrs)

Dilution, Diffusion- Fick's law of Diffusion, Advection, Dispersion of pollutants in Air plume behavior - Air pollution dispersion models - Gaussian Plume model; effect of boundaries: Inversion effects in air pollution.

Text Books

[1] Boeker and Grondelle, Environmental Physics. John Wiley.
[2] Faraoni, Exercises in Environmental Physics. Springer.
[3] Hinrichs and Kleinbach, Energy, Its Use and the Environment, Cengage Learning.
[4] Monteith and Unsworth, Principles of Environmental Physics, Academic Press.

Suggested Readings

[1] Mason and Hughes, Introduction to Environmental Physics, Taylor and Francis.

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