ST. MARY'S COLLEGE (AUTONOMOUS), THOOTHUKUDI

Re-Accredited with A Grade by NAAC

M.Sc. Physics

Syllabus 2017-2019

Intended Programme Outcome

PO No	Students of M.Sc., will be able to
PO1	A graduate with master degree has in depth and detailed functional knowledge of the fundamental theoretical concepts and experimental methods.
PO 2	The graduate has in depth knowledge of the topics of the research conducted by the researchers at the department of Physics, Chemistry, mathematics, computer science and microbiology. Students will communicate effectively, both orally and in writing and will prove that they can think critically and work independently while doing their thesis.
PO 3	Students will show that they have learnt laboratory skills, enabling them to take measurements in Physics, Chemistry, Computer science and Microbiology laboratories and analyse the measurements to draw valid conclusions.
PO4	Apply problems solving skills and the knowledge of physical science, computing sciences and biological sciences to solve real problems.
PO5	Demonstrate the basic understanding of various aspects of physical science, computing sciences and biological sciences.
PO 6	Specialized knowledge and practical training to address contemporary problems in academia and industry. Awareness of ethical issues and regulatory considerations while addressing societal needs for sustainability
PO 7	The program aims at providing specialization to the students in the various physics field
PO 8	Usage of subject and practical knowledge to design experiments, analyse and interpret data so as to reach to a valid conclusions.
PO 9	Develop awareness about usage of electricity and water consumption.
PO 10	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Course Structure (w.e.f 2017)

Semester – I

Subject	*Subject code*	*Title of the paper*	*Contact Hours/ Week*	*Credits*	*Max.Marks*		
					CIA	*ESE*	*Total*
Core I	17PPHC11	Classical Mechanics	6	5	40	60	100
Core II	17PPHC12	Mathematical Physics I	6	5	40	60	100
Core III	17PPHC13	Electronics and Experimental methods	6	5	40	60	100

Elective I	17PPHE11	Crystal growth & Thinfilms	6	5	40	60	100
Practical I	17PPHCR1	Electronics-I	6	4	40	60	100
			30	**24**	**200**	**300**	**500**

Semester – II

Subject	***Subject code***	***Title of the paper***	***Contact Hours/ Week***	***Credits***	***Max.Marks***		
					CIA	***ESE***	***Total***
Core IV	17PPHC21	Mathematical Physics II	6	4	40	60	100
Core V	17PPHC22	Electromagnetic Theory	6	4	40	60	100
Core VI	17PPHC23	Microprocessor and Microcontroller	6	4	40	60	100
Elective II (IDE)	17PPHE21	Bio-medical Instrumentation	6	5	40	60	100
Practical II	17PPHCR2	Non –Electronics	6	4	40	60	100
Self Study Course (Compulsory)	17PPHSS1	Physics for Lectureship-I		2		100	100
			30	**23**	**200**	**400**	**600**

Semester – III

Subject	***Subject code***	***Title of the paper***	***Contact Hours/ Week***	***Credits***	***Max.Marks***		
					CIA	***ESE***	***Total***
Core VII	17PPHC31	Quantum Mechanics – I	6	5	40	60	100
Core VIII	17PPHC32	Thermodynamics and Statistical Mechanics	6	5	40	60	100
Core IX	17PPHC33	Nuclear and Particle Physics	6	5	40	60	100
Project	17PPHP31		6	5	40	60	100
Practical III	17PPHCR3	C++ , Microprocessor and Microcontroller	6	4	40	60	100

Self Study Course (optional)	17PPHSS2	Physics for Lectureship- II	-	2		(100)	(100)
			30	**24+2**	**200**	**300**	**500**

Semester – IV

Subject	***Subject code***	***Title of the paper***	***Contact Hours/ Week***	***Credits***	***Max.Marks***		
					CIA	***ESE***	***Total***
Core X	17PPCC41	Nano Science and Technology	6	4	40	60	100
Core XI	17PPHC41	Quantum Mechanics – II	6	4	40	60	100
Core XII	17PPHC42	Atomic and Molecular Spectroscopy	6	4	40	60	100
Elective III	17PPHE41	Condensed Matter Physics	6	5	40	60	100
Practical IV	17PPHCR4	Electronics – II	6	4	40	60	100
			30	**21**	**200**	**300**	**500**

Master of Science (Physics)

Components	**Credit per Semester**	**No. of Courses**	**Credits**
Core	5	6	30
Core	4	6	24
Practical	4	4	16
Elective	5	3	15
Project	5	1	5

Self Study Course	2+2	2	4
		Total	94

PSO No	Students of M.Sc., Physics will be able to	PO Mapped
PSO 1	Demonstrate and understand the principles and theories of physics. These includes the following classical mechanics, Electromagnetic theory, Electronics and experimental methods, microprocessor and microcontroller, Quantum mechanics, thermodynamics and statistical mechanics, Nuclear and particle physics, Atomic and molecular spectroscopy, Nanoscience and technology and condensed matter Physics.	PO1
PSO 2	Apply algebra, calculus, tensors and complex variables to solve physics problems.	PO 4
PSO 3	Demonstrate the ability to do the lab experiments and apply the principles learnt in class	PO 3
PSO 4	• Undertake a major, individual project and report their results in a full scientific report oral or poster presentation. • Critically asses a project to evaluate the best strategy to achieve the desired outcome.	PO2
PSO 5	Extend and understand the impact of physics and science on society	PO5
PSO 6	Demonstrate written and oral communicating physics related topics	PO5
PSO 7	A research oriented learning that develops analytical and integrative problem-solving approaches.	PO 6
PSO 8	Help to communicate effectively on energy aspects with the society at large.	PO 9
PSO 9	To inculcate practical approach by using modern technology amongst the students in the field of physical science.	PO 8
PSO 10	During the course of the programme, students build a strong foundation in the fundamental principles of physics as well as acquire mastery over specific domain areas which enables them to carry out state-of-the-art research.	PO 10

SEMESTER - I			
CORE - I CLASSICAL MECHANICS			
Code : 17PPHC11	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits:5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Distinguish Lagrangian and Hamiltonian formulation	PSO1	An
CO 2	Describe the motion of bodies under the influence of the system of force	PSO5	U
CO 3	Using method of separation of variables, the solution for wave equation and heat equation can be obtained	PSO2	A
CO 4	By studying Euler's angles the motion of rigid bodies, molecules, planets, satellites and ships can be estimated	PSO3	A
CO 5	Provide extremely accurate results when studying large objects and speeds approaching the speed of light	PSO3	C
CO 6	Have a deep understanding of Newton's laws	PSO 10	U

Unit I: Fundamental Principles and Lagrangian Formulation

Mechanics of a particle – system of particles – constraints – D' Alembert's principle – Lagrange's equation –applications of Lagrange's formulation – Hamilton's principle – Lagrange's equation from Hamilton's principle – Advantages of variational principle formulation.

Unit II:Two Body Central Force Problems

Reduction to the equivalent one body problem –equivalent one dimensional problems and classification of orbits – equation of motion of first integrals – Virial theorem – Bertrand's theorem – Kepler's problems - scattering in a central force field - transformation of scattering problem to Laboratory coordinates.

Unit III: Hamilton's Formulation

Hamilton's equation from variational principle -- principle of least action – Canonical transformation-Lagrangean and Poisson's brackets – Equation of motion and conservation theorems in poisson brackets-Hamilton–Jacobi equation-Harmonic Oscillator problem-Separation of variables- Action angle variable.

Unit IV: Rigid Body Problems and Oscillatory Motion

Euler's angles – Angular momentum and kinetic energy of motion about a point – Euler's equations – Symmetric top applications – Theory of small oscillations – Frequencies of free vibrations and normal coordinates – Linear triatomic molecules.

Unit V: Relativistic Mechanics

The Special theory of Relativity – Lorentz transformation – Lorentz transformation in real four dimensional spaces –Covariant four dimensional formulations – Force and free energy equations in relativistic mechanics - The Lagrangian and Hamiltonian formulation of relativistic Mechanics.

Books for Study:

1.Herbet Goldstein ,Classical Mechanics, Second Edition, Narosa publishing House Pvt.Ltd.,New Delhi

Unit	Book No.	Sections
I	1	1.1-1.4, 1.6, 2.1, 2.3, 2.5
II	1	3.1-3.4, 3.6, 3.7, 3.10, 3.11
III	1	8.5, 8.6, 9.1, 9.4, 9.5, 10.1, 10.2, 10.4, 10.6
IV	1	4.4, 5.1, 5.5-5.7, 6.1-6.4
V	1	7.1-7.3, 7.5, 7.6, 7.8, 8.4

Books for Reference:

1. Dr.S.L.Gupta, V.Kumar & H.V.Sharma, Classical Mechanics –Nineth Edition 2001, Pragati Prakashan.
2. R.G. Takwalse and P.S. Puranik, Introduction to Classical Mechanics, 9th reprint 1988.
3. Suresh Chandra, Classical Mechanics, 2009 Reprint, Narosa publishing House Pvt.Ltd.,
4. Goldstein, Poole and safko, Classical Mechanics, Third Edition (2002), Person Education, Inc. New Delhi

SEMESTER - I			
CORE - II MATHEMATICAL PHYSICS - I			
Code : 17PPHC12	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits:5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Calculate the area of irregular shape by Green's theorem	PSO2	E
CO 2	Design feedback control systems with finite dimensional vector spaces	PSO2	C
CO 3	Apply special functions for Wireless communication and alternating current transmission	PSO5	A
CO 4	Understand the geometry interpretation of complex numbers	PSO6	U
CO 5	Resolve the incompleteness of the statistical interpretations relating to the summing of an infinite number of probabilities to yield a meaningful solutions	PSO2	C
CO 6	Be familiar with the main mathematical methods used in physics.	PSO 7	R

Unit I: Vector Calculus

Review of Vector Algebra – Gradient of a scalar field - Divergence of a vector function - Curl of a vector function – Gauss Divergence theorem – Stokes's theorem – Green's theorem (Proof only).

Linear vector space: Liner independence of vector and dimension – Basis of expansion theorem – Inner product and unitary spaces –Orthonormal sets – Schmidt's orthogonalisation method.

Unit II: Linear Algebra

Matrices: Review - Special types - Transpose - Conjugate – Conjugate Transpose - Symmetric and AntiSymmetric - Hermitian and Skew-Hermitian - Determinant - Singular and Non-Singular - Adjoint – Inverse - Orthogonal - Unitary - Trace - Rank - Cramer's rule - Eigen values, Eigen-vectors: Characteristic equation of a Matrix - Cayley-Hamilton theorem.

Unit III: Special Functions I and Partial Differential Equations

Legendre Function: Legendre's Equation - Generating Function – Rodrigue's Formula – Orthogonality - Recurrence Formulae - Bessel Function: Bessel's Function of the First kind – Generating Function – Recurrence Formulae.

Introduction - Laplace equation (Cartesian - 3D only) – Heat flow equation (3D only) - Equation motion for the vibrating string (D'Alembert's solution only).

Unit IV: Complex Analysis

Complex variables– Limits and continuity – Differentiability –Analytic function- Cauchy-Riemann equations(necessary and sufficient condition, polar form)– Cauchy theorem – Cauchy integral formula – Taylor's theorem – Laurent theorem - Singular points – Residues – Method of finding residues- Residue theorem – Evaluation of definite integrals(unit circle type & evaluation $\int_{-\infty}^{+\infty} \frac{f_1(x)}{f_2(x)} dx$ only).

Unit V: Group Theory

Group, subgroup, classes – invariant, subgroups, factor groups –homomorphism and isomorphism – grouprepresentation - reducible and irreducible representation – Schur's lemmas, great orthogonality theorem – character table.

Continuous Groups: Lie groups and lie algebra – SO (3) group – SU (2) and SU (3) unitary groups.

Books for study:

1. Satya Prakash, Mathamatical Physics, Sultan Chand & Sons, New Delhi.
2. H.K.Dass ,Mathematical Physics, S.Chand & Company LTD, Fourth Revised Edition 2004
3. Mathematical Physics, P.K. Chattopadhyay, New Age International Publishers, Reprint (2001)

Unit	Book No.	Chapters / Sections
I	1	1.1,1.2,1.4,1.5,1.7,1.9,1.12,1.16
II	1	2.2, 2.5-2.11, 2.14, 2.19, 2.23, 2.27, 2.31-2.32
III	1	6.7-6.11,6.17,6.21,6.22,8.2,8.11,8.13
IV	2	7.3-7.10,7.31-7.33, 7.39-7.47
V	3	8.1-8.7, 8.11-8.13

Books for reference:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and sons (Asia), 8th Edition (2005).
2. B. D Gupta, Mathematical Physics, Vikas Publishing house PVT LTD, Fourth Edition 2010

SEMESTER - I			
CORE - III	**ELECTRONICS ANDEXPERIMENTAL METHODS**		
Code : 17PPHC13	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits:5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Relate fundamental concept of semiconductor physics	PSO1	U
CO 2	Develop skill to build digital circuits	PSO3	A
CO 3	Analyse and design various combinational and sequential circuit	PSO3	An
CO 4	Identify basic requirements for a design application and propose a cost effective solution	PSO 5	A
CO 5	Discuss the theory of transducers and its uses	PSO1	C
CO 6	Construct wave form generators	PSO1,3,4	C

UnitI: Semiconductor Physics

Energy band theory of semiconductor-Fermi level intrinsic & extrinsic semiconductor-p-n junction-forward & reverse bias

Diode: tunnel diode-photodiode-LED-LCD –photo conductor-Gunn diode-Hall effect

UnitII:OPAMPApplications

Basics of OPAMP –inverting & non-inverting OP-AMP-differential amplifier – Analogintegrationanddifferentiation – Comparators. Waveform generator: Square wave generator-Saw-tooth wave generator -triangular wave generator -Schmitttrigger

UnitIII:D/A and A/Dconversion

Variable-resistornetwork – resistive divider-Binaryladder – D/Aconverter – D/Aaccuracyandresolution – A/Dconverter – Simultaneousconversion – Countermethod – continuousA/Dconversion – A/Dtechniques – Dual-slopeA/Dconversion-A/Daccuracyandresolution

Unit IV:CountersandRegisters

Counters – Asynchronouscounters – Synchronouscounters – Changing the countermodulus – Decade counter – Typesofregisters – Serialin-Serialout – Serialin-Parallelout – Parallelin-Serialout – Parallelin-Parallelout – Universal Shift registers

UnitV:Transducers:

Transducer-electric transducer-classification of transducer– Characteristics and choice of Transducers - StrainGauges- Capacitive transducer – Piezoelectric transducer

Booksforstudy:

1.S.K Kakani, K.C. Bhandari,Electronics Theory and Applications, 2014 reprint, New Age International Publishers, New Delhi.

2. Jacob Milman and Christos C.Halkias, Integrated Electronics, Tata Mc Graw Hill Edition,India, 1991.

3.DonaldP.Leach,AlbertPaulMalvinoandgoutamSaha, DigitalPrinciplesandApplications,Sixth edition 2008, The McGRAW-Hill Publishing CompanyLtd.,New Delhi.

4. A.K.Sawhney – ElectricalandElectronicMeasurementsandInstrumentation – DhanpatRaiSons, EducationalandTechnicalPublishers,Delhi,Fourthedition

Unit	Book No.	Pages
I	1	6-11,12-14,18-19,27-28,38-42,49-51,51-53,55-59,65-67,72-74
II	2	566-578,612-616,640-642,649-655
III	3	438-472
IV	3	309-324,342-368,381-384,
V	4	935-949,964-966,1014-1023,1028-1038

SEMESTER - I			
ELECTIVE I	**CRYSTAL GROWTH & THINFILMS**		
Code :17PPHE11	**Hrs/Week: 6**	**Hrs/Semester:90**	**Credits: 5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Generate an understanding of self assembly during the process of growth	PSO4	A
CO 2	Apply the process skills of scientific inquiry during experimentation	PSO3	A
CO 3	Understand the foundation of SEM, TEM and be able to apply these techniques to their own research projects	PSO6	U
CO 4	Discuss the differences and similarities between different deposition techniques.	PSO1	C
CO 5	Motivate selection of deposition techniques for various applications	PSO3	C
CO 6	Create Thin Films by thermal evaporation and flash evaporation	PSO1,3,5	C

Unit I: Introduction

Crystal growth – significance of Single crystals - crystal growth techniques – chemical physics of crystal growth. Nucleation – Theories of nucleation - classical theory of nucleation – Heterogeneous nucleation – Kinetics of crystal growth- singular and rough faces – KSV theory - BCF theory of solution growth.

Unit II: Growth Techniques

Solution growth : Low temperature solution growth – crystal growth system – Seed preparation – mounting and seasoning – High temperature solution growth. Gel growth: varies of types of gel – Experimental procedure – Biological crystallization .

Unit III: Charatecterisation Technique

Diffraction analysis – X-ray diffraction- electron & neutron diffraction- interpretation of diffraction pattern – cell parameter determination.

Thermal analysis – thermo gravimetric analysis - differential thermal analysis- differential scanning calorimeter.

TEM, instrumental details - SEM – AFM.

Microhardness (Nano hardness) – Classificatrion of hardness test – Vickers hardness test – Knoop hardness test .

Unit IV: Thin film

Preparation of thin films: thermal evaporation- flash evaporation -electron gun beam method – cathodic sputtering- chemical vapour deposition – chemical deposition.Thickness measurements – ellipsometry – interferometry.

Unit V: Technological application of thin film

Thermistor-varistor-strain gauge element-capacitor-hall probe element-active devices-micro electronics, IC and other applications

Application of thin film dielectrics and optical films

Discrete resistive components: resistors-carbon films-oxide and nitride films- cermet films-metal films

Books for study:

1. Dr. P .Santhana Ragavan and P.Ramasamy ,Crystal growth processes and methods.
2. A.Goswami, Thin film fundamentals , First Edition 1996, New age international, (p),Ltd. New Delhi.

3.Fundamentals of optical spectroscopic and X-ray mineralogy, Sachinath Mitra,Wiley eastern Ltd,New Delhi.
4.Material Science,S.L.Kakani,Amit Kakani,Second Edition Reprint 2011,New age international, (p),Ltd. New Delhi.
5. Material Science, V.Rajendran, Mc graw hill, First reprint 2012, New Delhi.

Unit	Book No.	Section
I	1	1.1, 1.2, 1.4, 1.5, 2.2, 2.2.1-2.2.3, 2.3, 2.3.2, 2.3.4, 2.3.5
II	1	3.2,3.3,3.5,3.6,4.1,4.2,4.7,4.8,5.4,5.4.3,5.4.6,5.4.7,5.2.1
III	3 4 5	7.6,7.9,7.19,7.21,7.22 Chapter 3 :30 75 – 82, 84 – 86,
IV	2	Chapter I-4.1, 4.2, 5-9,9.2.2, 9.2.3
V	2	Chapter 1 :-21,Chapter 11 :13,Chapter 14 :2-7,.

Books for reference:

1. J.C.Brice, Crystal growth processes
2. B.R.Pamplin, Crystal growth, second edition
3. D.T.J.Hurle , Crystal pulling from melt
4. V.Raghavan , Material science & Engineering – A first course
5. William .D.Callister,Jr., Martial science & Engineering an introduction ,V edition

SEMESTER - I			
PRACTICAL I	**ELECTRONICS –I**		
Code : 17PPHCR1	**Hrs/Week:- 6**	**Hrs/Semester:- 90**	**Credits:4**

(Any 12 Experiments)

1. Modulus counters 2 to 10
2. FET Characteristics
3. UJT Characteristics
4. D/A converter
5. Triangular wave and Ramp generator
6. A/D converter
7. RS,$\overline{RS}$ flip flops using NAND and NOR gates
8. JK, D and T flip flops using NAND and NOR gates.
9. JK Master Slave flip flop
10. Serial in Parallel out shift register
11. Multiplexer and Demultiplexer
12. K map simplification and implementation of basic and universal gates by SOP and POS
13. BCD adder subtractor
14. Design of asynchronous counter
15. Verification of Boolean algebra

SEMESTER - II			
CORE IV	MATHEMATICAL PHYSICS II		
Code : 17PPHC21	Hrs/Week: 6	Hrs/Semester: 90	Credits: 4

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Analyse the experimental data with the aid of Fourier transform	PSO5	An
CO 2	Understand the basic of tensor calculus and to describe motion and deformation of body	PSO2	U
CO 3	Recall the basic notations of generating functions and special functions	PSO1	R
CO 4	Apply computational techniques to solve a wide range of numerical problems arising in physics	PSO3	A
CO 5	Explain the concepts of Green's functions and solve boundary value problems	PSO1	E
CO 6	Solve Linear Differential Equations of First and Second order	PSO2	A

Unit I: Probability and Integral Transforms

Probability: Probability – definitions - Binomial distribution, Poisson distribution – Gaussian distribution.

Integral Transforms: Fourier Series- Fourier integral – Fourier transform - Linearity – first and second shifting theorems – Laplace transform – transforms of derivative and integral – inverse Laplace transform – partial fractions.

Unit II: Tensors

Notations and conventions – tensors of second rank – equality and null tensor – addition and substraction – outer product of tensors – inner product of tensors – symmetric and antisymmetric tensor – Kronecker delta – quotient law – metric tensor – Cartesian tensor – isotropic tensor – stress, strain and Hooke's law.

Unit III: Special Functions II

Hermite functions: Hermite Differential Equation – Hermite Polynomials – Recurrence Formulae – Rodrigue's Formula – Orthogonality.Laguerre function: Differential equation – Laguerre polynomial – Generating Function – Rodrigue's Formula – Recurrence Relation – Orthogonal Property.

Unit IV: Numerical methods

Solution of Algebraic and Transcendental equations: Newton – Raphson's method - Solution of Linear Algebraic Equations: Gauss elimination, Interpolation: Lagrange's interpolation– Inverse interpolation – Finite differences– Newton's forward and backward interpolation - Numerical Integration :Trapezoidal rule - Simpson's $1/3^{rd}$ and $3/8^{th}$ rule - Initial Value Problems:Solving first order differential equations using Runge-Kutta methods.

Unit V: Greens Function and Linear differential equations of first & Second Order

Green's function for one dimensional problems and properties – Green's function in higher dimensions. Application: Poisson's equation.

Linear differential equations –Equations of first order and higher degree-Linear differential equations of second order with constant coefficients – Method for finding the complementary function – Rules to find particular integral.

Books for study:

1. Satya Prakash, Mathematical Physics, Fourth revised Edition 2004, Sultan Chand &Sons.
2. Matrices and tensors in Physics, A.W. Joshi, New Age International Publishers, Revised Third Edition (1995), Reprint 2010.
3. Numerical Methods - A. Singaravelu, Meenakshi Agency, Chennai
4. P.K. Chattopadhyay, Mathematical Physics, New Age International Publishers, Reprint (2001) and [Unit-V Chapter 6].
5. H.K.Dass ,Mathematical Physics, S.Chand & Company LTD, Fourth Revised Edition 2004

Unit	Book No.	Chapters / Sections
I	1	11.2, 11.20, 11.21, 11.22,7.1,7.3, 7.5, 7.6, 7.10, 9.2, 9.3, 9.9, 9.11, 9.12, 9.15, 9.20
II	2	15.2, 15.5, 16.1-16.4, 16.6, 16.7, 17,18.1, 19.3-19.5
III	1	6.29, 6.31 - 6.33, 6.35 – 6.38
IV	3	1.1, 1.16, 1.53, 2.1, 2.13, 2.59, 2.61, 2.75, 3.27, 3.31, 4.54
V	4 5	6.2, 6.5, 6.6, 3.14-3.18

Books for reference:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and sons (Asia), 8th Edition (2005).
2. B D Gupta, Mathematical Physics, Vikas Publishing house PVT LTD, Fourth Edition 2010

SEMESTER - II			
CORE V	**ELECTROMAGNETIC THEORY**		
Code : 17PPHC22	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 4**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Recall the fundamental concepts of electromagnetic theory	PSO1	R
CO 2	Formulate potential problems within electrostatics, magnetostatics	PSO1	C
CO 3	Construct Maxwell's equations and identify each mathematical operator and physical quantity in the equations	PSO2	A
CO 4	Able to discuss methods used to analyze different waves and conduct a mock trial on electromagnetic radiation	PSO6	A
CO 5	Distinguish transmission lines and waveguides and analyze propagation of signal in different modes	PSO5	An
CO 6	Calculate the work done to move a point charge	PSO1,2	A

Unit I: Electrostatics

Coulomb's Law - Gauss Law – Poisson's Equation and – Laplace's Equation – Work Done to move a point charge – Energy of a point charge and continuous charge distribution – Method of Images – Electric field in dielectric material – Gauss Law in the presence of dielectric – Susceptibility , Permittivity and Dielectric constant of linear dielectrics.

Unit II:Magnetostatics

Biot-Savart's and Ampere's Law - Magnetic vector potential – Multipole expansion of the vector potential – Effects of a Magnetic field on atomic orbits – Bound current and its Physical Interpretation – Ampere's law in Magnetized Materials – Magnetic Energy.

Unit III:Electrodynamics

Maxwell Equation (Both Differential and Integral Formulations) – Boundary Conditions On field vectors D, E, B and H -Scalar and Vector Potentials - Gauge transformations – Lorentz and Coulomb Gauges - Poynting Vector and Poynting's Theorem – Maxwell's Stress Tensor.

Unit IV:Electromagnetic Waves and Radiations

The Wave Equation for E and B – Propagation of EM Waves in Linear media – Reflection and transmission at normal and oblique incidence – EM waves in conductors – Radiation – Electric dipole radiation - Magnetic dipole radiation.

Unit V: **Wave Guides**

Wave guides – Rectangular wave guide TE - Rectangular wave guide TM mode – Circular wave guide – resonant cavities-TE Mode –TM mode

Books for Study:

1. David J.Griffiths, Introduction to Electrodynamics, Pretice hall of India,2nd edition(1989)
2. Satya Prakash, Mathematical Physics, Fourth revised Edition 2004, Sultan Chand &Sons.

Unit	Book No.	Sections
I	1	2.1.2, 2.2.1, 2.3.3, 2.4.1-2.4.3, 3.2.1, 4.2.3, 4.3.1, 4.4.1
II	1	5.2, 5.3.4, 5.4, 5.4.3, 6.1.3, 6.2.1, 6.2.2, 6.3.1
III	1	7.3, 7.3.5, 7.4.1, 7.4.2, 7.4.3, 7.5.2, 7.5.3
IV	1	8.1.2, 8.2.3, 8.2.5, 8.3, 9.1.2, 9.1.3
V	2	8.25-8.28

Books for Reference:

1. Paul Lorraius and Dale Corson, Electromagnetic Fields and Waves, CBS Publishers & distributors, 2nd edition 2003

SEMESTER - II			
CORE VI MICROPROCESSOR AND MICROCONTROLLER			
Code :17PPHC23	Hrs/Week: 6	Hrs/Semester: 90	Credits: 4

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Understand and explain bus transactions, memory organisation and address decoding, basic I/O interfaces and port addressing	PSO1	U
CO 2	Ability to apply and implement learned algorithm design techniques and data structures to solve the problems	PSO3	A
CO 3	Analyze concepts associated with interfacing a microprocessor to memory and to I/O devices	PSO1	An
CO 4	Examine how to control components of a microprocessor based system through the use of interrupts	PSO5	An
CO 5	Recall a microprocessor programming model at a level that enables to write assemble language programs for the processor meeting given specifications	PSO1	R
CO 6	Construct a microprocessor based stepper motor	PSO1	C

UnitI: Microprocessor Architecture and Instructionset

Intel 8085 Architecture-Instruction format-8085 programming model-instruction classification-8085Instructionset – Datatransferoperations -Arithmeticinstructions – Logicoperations-Branchoperations.

Unit II:Microprocessor Programming and Interrupts

Writing assembly language programs-Programmingtechniques: Looping,CountingandIndexing –Stack-Subroutine-Examples of assembly language programming: Addition-subtraction-multiplication-Division (indifferent modes)-Ascending and descending order-to find the largest and smallest number in data array-8085 Interrupt.

Unit III:Microprocessor Interfacing

Techniques for time delay-Basic interfacing concept-8255(PPI)-Interfacing Keyboard and Seven segment Display- Microprocessor based stepper motor-waveform generator using ADC and DAC

Unit IV:Basics of 8051 microcontroller

Introduction – 8051 Microcontroller hardware –oscillator and clock- Input/output Pins, Ports and Circuits – External Memory – Counters and Timers – Serial Data Input/output – Interrupts.

Unit V: Microcontroller Programming

Addressing mode of microcontroller 8051-arirhmetic and logical instruction-8051 assembly language programmes: addition, subtraction, division, multiplication-interfacing 8051 with LED display and keyboard.

Books for study:

1. RameshGaonkar,MicroprocessorArchitechture,ProgrammingandApplicationswiththe8085, PenramInternationalPublishing(India)PrivateLimited,Fifthedition,2011.

2.Kenneth Ayala, The 8051 Microcontroller, 3rd Impression 2011, Cengage Learning India P Ltd, New Delhi.

3.Microcontroller8051,D.karuna Sagar,2011 print, Narosha publishing house PVT Ltd,Delhi

Unit	Book No.	Pages
I	1	65-79,140-193
II	1	193-198,210-223,276-282,285-295,358-366
III	1	256-262,104-110,448-470
IV	2	62-96
V	3	4.1-4.13, 5.1,12.4, 12.5

Books for reference:

1.Aditya.P.Mthur, Introduction to Microprocessors , 3rd Edition, Tata McGraw Hill Education P Ltd, New Delhi.

2. B.Ram and Sanjay Kumar,Fundamental of microprocessors and microcontrollers,Seventh revised Edition,Dhanpat rai Publications (P) Ltd, New Delhi

SEMESTER - II			
Elective II(IDE) BIO-MEDICAL INSTRUMENTATION			
Code :17PPHE21	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Acquire an adequate knowledge of the physiological systems of the human body	PSO1	U
CO 2	Relate the knowledge of the physiological systems to the parameters that have clinical importance	PSO5	U
CO 3	Categorize the fundamental principles of equipments those are actually in used at present	PSO6	An
CO 4	Recommend the safety instruments in hospitals	PSO5	E
CO 5	Adapt the advancement in biomedical instrumentation	PSO5	C
CO6	Interpret ECG, EMG and EEG readings	PSO3	An

Unit I: Human physiological systems and transducers

Cells and their structure-resting and action potentials-design of medical instruments-Design of medical instruments-Components of the bio-medical instrument system

Electrodes: electrode potential-purpose of electrode paste-electrode material-micro electrodes-depth and needle electrodes-surface electrodes.

Transducers Types: active -magnetic induction type-piezoelectric-photovoltaic-thermo electric-passive-resistive-magnetostirctive ultrasonic-pioezoelectric ultrasonic.

Unit II: Bio-Potential Recoders

Introductions-characteristics

ECG: origin-lead configuration-recording setup-practical consideration-analysis

EEG: origin-brain waves-placement of electrodes-recording set up-analysis

EMG:recording set up-determination of conduction velocities in motor nerves

Unit III: Physiological Assist Devices and Operation Theatre Equipments

Pacemakers: energy requirements to excite heat muscle-methods of stimulation-different modes of operation:Ventricular synchronous pacemaker-Atrial synchronous pacemaker

Kidney Machine: Renal function-dialysis-hemodialysis-peritoneal dialysis

Ventilators-anesthesia machine.

Unit IV: Safety Instruments

Radiation Safety Instrumentation-Physiocological Effect due to 50 Hz current passage – Microshock and Macroshock – Electrical accidents in hospitals – Devices to protect against electrical hazards.

Unit V: Advances in Biomedical Instrumentation

Computers in medicine – Lasers in medicine – Endoscopes – cryogenic surgery – Nuclear Imaging techniques – Computer Tomography – Thermography-MRI – Biomaterials.

Book for Study:

1. Biomedical Instrumentation, Dr.M.Arumugam, Tenth reprint 2013, Anuradha publications, Chennai.

Unit	Book no.	Sections
I	1	1.2,1.5,2.2,2.32.4 -2.4.7,2.5-2.5.7.2.5.18,2.5.19
II	1	4.1,4.2,4.3-4.3.5,4.4-4.4.5,4.5-4.5.2
III	1	5.2,5.8,6.8,6.9
IV	1	9.1 – 9.6
V	1	10.1-10.6,10.7, 10.8, 10.10,10.14

SEMESTER - II			
Self study Paper I (Compulsory) Physics for Lectureship-I			
Code :17PPHSS1	**Hrs/Week: -**	**Hrs/Semester: -**	**Credits: 2**

Unit I : Mathematical Methods of Physics

Dimensional analysis. Vector algebra and vector calculus. Linear algebra, matrices, Cayley-Hamilton Theorem. Eigenvalues and eigenvectors. Linear ordinary differential equations of first & second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem.

Unit II: Classical Mechanics

Newton's laws. Dynamical systems, Phase space dynamics, stability analysis. Central force motions. Two body Collisions-scattering in laboratory and Centre of mass frames. Rigid body dynamics-moment of inertia tensor. Non- inertial frames and pseudoforces. Variational principle. Generalized coordinates. Lagrangian and Hamiltonian formalism and equations of motion. Conservation laws and cyclic coordinates. Periodic motion: small oscillations, normal modes. Special theory of relativity-Lorentz transformations, relativistic kinematics and mass–energy equivalence.Dynamical systems, Phase space dynamics, stability analysis. Poisson brackets and canonical transformations. Symmetry, invariance and Noether's theorem. Hamilton - Jacobi theory.

Unit III: Electromagnetic Theory

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces. Scalar

and vector potentials, gauge invariance. Electromagnetic waves in free space. Dielectrics and conductors. Reflection and refraction, polarization, Fresnel's law, interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields. Dispersion relations in plasma. Lorentz invariance of Maxwell's equation. Transmission lines and wave guides. Radiation-from moving charges and dipoles and retarded potentials.

Unit IV: Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell relations, chemical potential, phase equilibria. Phase space, micro-and macro-states. Micro-canonical, canonical and grand-canonical ensembles and partition functions. Free energy and its connection with thermodynamic quantities. Classical and quantum statistics. Ideal Bose and Fermi gases. Principle of detailed balance. Blackbody radiation and Planck's distribution law.First-and second-order phase transitions. Diamagnetism, paramagnetism, and ferromagnetism. Ising model. Bose-Einstein condensation.

Unit V:Electronics and Experimental Methods

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo-and hetero-junction devices), device structure, device characteristics, frequency dependence and applications. Opto-electronic devices (solar cells, photo-detectors, LEDs). Operational amplifiers and their applications. Digital techniques and applications (registers, counters, comparators and similarcircuits). A/D and D/A converters. Microprocessor and microcontroller basics. Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least squares fitting.

Book for Study:

1. Truman's Series UGC-CSIR JRF/NET Physical Sciences, Danika Publishing Company,New Delhi

SEMESTER - II			
PRACTICAL – II	**NON-ELECTRONICS**		
Code :17PPHCR2	**Hrs/Week: 6**	**Hrs/Semester:90**	**Credits: 4**

(Any 12 Experiments)

1. Hall Effect, Carrier concentration.
2. BH curve tracing and Hysteresis loss
3. Elliptical fringes – Young's modulus
4. Resistivity of semiconductor by Four Probe method at different temperatures
5. Resistivity two probe measurement at different temperatures.
6. Band Gap measurement
7. Determination of dielectric constant for Ferro electric substance
8. LASER Experiment: Thickness of insulation of a wire by Diffraction method
9. Solar spectrum
10. Iodine Absorption Spectra
11. Polarizability of liquids using hollow prism
12. Susceptiblity-Quincke's method:
13. Hyperbolic fringes - Young's modulus of glass plate
14. Rydberg's constant
15. Ultrasonic interferometer
16. Refractive Index of the liquid at various concentrations using laser
17. Wave length of He-Ne laser
18. Resolving Power of grating and prism using spectrometer.

SEMESTER - III			
CORE - VII	**QUANTUM MECHANICS-I**		
Code :17PPHC31	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Develop a knowledge and understand the meaning of uncertainty principles, energy eigen function and boundary conditions	PSO1	C
CO 2	Able to numerically solve the linear harmonic oscillator and describe fundamentals	PSO2	A
CO 3	Compile the knowledge of role of angular momentum and the Pauli spin matrices using ladder operators	PSO1	C
CO 4	Relate the matrix formalism to the use of basic states and solve simple problems in that formalism	PSO2	U
CO 5	Make use of the perturbation theory and variation methods in applications of ground state of He atom	PSO2	A
CO 6	Have a deep understanding of the mathematical foundations of quantum mechanics	PSO1	U

Unit I: Formalism of Quantum Mechanics

Inadequacy of classical Physics - Uncertainty Principle – Interpretation of wave function – Statistical Interpretation – Normalisation of Ψ – Probability current density – Expectation value – Ehrenfest's theorem – Energy eigen functions – separation of wave equations – Boundary and continuity condition – Energy eigen values in one dimension – discrete energy level – continuous energy eigen functions – discrete and continuous eigen values in 3D – 1D square well potential.

Unit II: Eigen functions and eigen values

Normalisation – Orthonormality – Momentum eigen functions – The Dirac function.

Discrete Eigen Values: Bound state - Linear Harmonic Oscillator – Spherical symmetric potential in 3D - Hydrogen atom.

Unit III: Angular Momentum

Angular momentum operator – Eigen values and eigen functions of L^2 – commutation relations – Angular momentum and rotations – Ladder operators – the constants C_+ and C_- - Angular momentum corresponding to j = ½ and the Pauli spin matrices, wave function and equations – combination of two angular momenta – C.G coefficient.

Unit IV: Matrix formulation

Transformation theory – Unitary matrix – Transformation of Hamiltonian with W, U, V – Hilpert space – Dirac bra and ket notation - Schrodinger's picture – Hisenberg's picture – Interaction picture – Matrix theory of harmonic oscillator.

Unit V: Approximation methods

Perturbation theory in non-degenerate cases – Applications to ground state of He atom, Harmonic oscillator – Stark effect in Hydrogen – Variation method – Application to ground state of He atom - WKB Approximation.

Books for Study:

1. L.I.Schiff, Quantum Mechanics , IIIEdition,McGraw Hill,1968
2. Ajoy Ghatak, S.Lokanathan, Quantum Mechanics Theory and Applications, 5th Edition, Macmillan India Ltd, NewDelhi.
3. Quantum Mechanics ,Chatwal Anand, Fourth Edition,1993,Himalaya Publishing house,Bombay,

Unit	Book no.	Sections / Page No
I	1	2-3, 7-8,24-32, 34-44
II	1	47-50, 53-55, 66-83, 88-98
III	2 3	212 – 221, 309 – 318 653 - 659
IV	1	155-159, 163-166, 168-173, 180 - 185
V	3 2	405-410, 505 – 508 380 - 384

Books for Reference:

1. Richard L.Liboff , Introductory Quantum mechanics, Fourth edition, Pearson Education 2003.
2. SathyaPrakash, Advanced Quantum Mechanics, Reprint 2013,Keda Nagth and Ram Nath Publications, Meerut.
3. P.M.Mathews and K.Vengatesan, A text book of Quantum Mechanics, 38 reprint 2007, Tata Mc Graw Hill Publishing Company Ltd, NewDelhi.
4. S.N.Biswas, Quantum Mechanics, 2011 Reprint, Books and Allied P Ltd, Kolkata.
5. Ajoy Ghatak, S.Lokanathan, Quantum Mechanics Theory and Applications, 5th Edition, Macmillan India Ltd, NewDelhi.
6. Vimal Kumar Jain, Introduction to Quantum Mechanics, 2010 Edition, Narosa publishing P Ltd, NewDelhi.

SEMESTER - III			
CORE VIII THERMODYNAMICS AND STATISTICAL MECHANICS			
Code : 17PPHC32	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits:5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Acquire working knowledge of the zeroth, first, second and third law of thermodynamics	PSO1	C
CO 2	Apply statistics in different systems containing atoms and molecules	PSO2	A
CO 3	Construct the partition function for calculations about the microcanonical, canonical, grand canonical ensemble	PSO2	An
CO 4	• Recover the loss of thermodynamics and equipartition theorem from the statistical description using microstates • Uses Fermi Dirac and Bose Einstein statistics according to the spin of the particles	PSO6	E
CO 5	Acquire knowledge about phase transitions and fluctuations in ensembles	PSO1	C
CO 6	Analyse energy changes in chemical reaction using the first law of thermodynamics	PSO1	An

Unit I: Thermodynamics

Zeroth, First, Second and Third law of thermodynamics – Entropy – Maxwell's thermodynamic relations – Thermodynamic potentials – Chemical potential.

Unit II: Basis of Statistical Mechanics

Phase space – Ensemble – Liouville theorem – Conservation of extension in phase – Equation of motion – Equal a priori probability – Statistical Equilibrium – Microcanonical Ensemble – Quantisation of Phase space – Classical limit – Symmetry of wave functions – Effect of symmetry of counting – Various distributions using microcanonical ensemble.

Unit III: Ensemble

Gibbs paradox – Sackur-Tetrode equation – Entropy of a system in contact with a heat reservoir- Ideal gas in canonical ensemble – Grand canonical ensemble – Ideal gas in grand canonical ensemble – Comparison of various ensembles – Quantum distributions using other ensembles.

Unit IV: Statistical Thermodynamics

Macrostates and microstates – Bose-Einstein distribution function – Fermi-Dirac distribution function – Maxwell-Bolltzman distribution function – Partition function – Thermodynamic properties of a system - Bose-Einstein condensation – Einstein and Debye theories of the specific heat capacity of a solid – Blackbody radiation.

Unit V: Ising model and Fluctuations

Phase transitions of the second kind – Ising model – Bragg-Williams approximations – Fowler-Guggenheim approximation – One dimensional Ising model.

Fluctuations in ensembles – concentration fluctuations in quantum statistics - One dimensional random walk – Brownian motion.

Book for Study:

1. Heat and thermodynamics, V N Dass, First Edition, 2005, Dominant Publishers , Delhi.

2. Statistical Thermodynamics, M.C Gupta, Reprint 2009, New age international P Ltd, New Delhi.
3. Thermodynamics, Kinetic Theory and Statistical Thermodynamcis, Sears Salinger, Third edition, Narosa publishing house pvt Ltd, New Delhi.
4. Statistical Mechanics, B.K Agarwal, Melvin Eisner, Reprint 2002, New age international P Ltd, New Delhi.

Unit	**Book no.**	**Sections / Page No**
I	1 2 3	1-2, 14-19, 70-71, 76-77,154-160, 173-187 5.5 7.7
II	4	1.2,1.3,1.5-1.10, 2.2,2.4-2.7
III	4	3.5, 3.6, 4.2,4.3,4.6 - 4.9
IV	3 4	11.3,11.9,11.10, 11.13,11.14, 11.5,13.1,13.2,13.3 6.2
V	4	11.1 -11.4, 11.6,10.3-10.6

Books for reference:

1. Kerson Huang, Statistical Mechanics, John Wiley & Sons, Inc., New York, Second edition, 1987.
2. A.K.Dasgupta, Fundamentals of Statistical Mechanics, New Central Book Agency (P) Ltd., Calcutta, 2000.
3. Sears and Zymanski, Statistical Mechanics, McGraw Hill Book Company, New York, 1961.
4. Federick Reif., Fundamentals of Statistical and thermal Physics, McGraw Hill International Editions, Singapore, 1985.

SEMESTER - III			
CORE - IX NUCLEAR AND PARTICLE PHYSICS			
Code :17PPHC33	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	List the basic properties of atomic nuclei	PSO1	R
CO 2	Classify the different types of nuclear reactions	PSO5	U
CO 3	Categorize the different types of nuclear models and their properties	PSO6	An
CO 4	Discuss the nuclear forces and the theories related to it	PSO1	C
CO 5	Classify the types of elementary particles	PSO1	U
CO 6	Discuss the Quark theory of Nuclei	PSO1	A

Unit I:Introduction

Basic Properties of atomic nuclei -Gamow's theory of alpha d**e**cay - Fermi theory of beta decay-Shape of the beta ray spectrum-Angular momentum and parity selection rules-Parity violation-detection and properties of neutrino-Gamma decay-Multipole transitions in nuclei-Selections rules-Internal conversion-Nuclear isomerism.

Unit II:Nuclear Reactions

Pick up,break up, knock out and stripping nuclear reactions-Balance of mass and energy in nuclear reactions –Q equation-Solution of the equation- Exoergic and endoergic reactions-Compound nuclear theory-Reciprocity theorem-detailed balance-Breit Wigner one level resonance formula-Optical Model-Hot Nuclei-Statistical theory.

Unit III:Nuclear Models

Liquid drop model-Potential barrier for fission-Bohr Wheeler theory of nuclear fission-Barrier penetration-Decay probabilities for spontaneous fission-Neutron induced fission-Asymmetric fission-Energy released in fission-Fission chain reaction –Nuclear shell model-Evidences that led to the shell model-spin orbit coupling-Angular momenta and parities of nuclear ground states-Magnetic moments-Schmidt line.

Unit IV:Nuclear Forces

Ground and excited states of deuteron-Magnetic dipole and electric quadrupole moments of the deuteron-Exchange forces –Meson theory of nuclear force-Nucleon-nucleon scattering at low energy-Effective range theory-Spin dependence and charge independence of nuclear forces.

Unit V:Elementary Particles

Classification of elementary particles-Conservation laws-Classification of hadrons-SU (2) and SU (3) symmetries-baryon octet-Meson octet-Baryon decuplet - Gellmann-Okubo mass formula-Quark theory of nuclei.

Book for study:

1. D. C. Tayal, Nuclear Physics,Reprint 1985, Himalaya Publishing House.
2. M. L. Pandya and R. P. S. Yadav, Elements of Nuclear Physics, Revised Reprint 2008,Kedar Nath & Ram Nath publications, Meerut.

Unit	Book No.	Sections
I	1	1.3,1.6,1.7,1.8,5.6,6.5,7.4,7.6
	2	8.5,8.6,8.7,9.8
II	1	10.19,10.11,10.14,10.15,10.17
	2	11.2,11.10
III	1	9.3,9.4
	2	12.7,12.8
IV	1	9.4
V	1	16.2,16.4,16.20
	2	13.1,13.9,13.10,13.11

Book for Reference:

1.Irving Kaplan, Nuclear Physics, Nineteenth Reprint, Second Edition,Addision-Wesley publishing company, USA.
2.R.C. Sharma, Nuclear Physics, Sixth revised edition, K.Nath & Co Publications, Meerut.
3.V.Devanathan, Nuclear Physics, Revised Reprint 2008, Narosa Publishing,New Delhi.

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SEMESTER - III			
PROJECT			
Code :17PPHP31	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 5**

FORMAT FOR PREPARATION OF PROJECT REPORT FOR M.Sc. Physics

1.IDENTIFICATION OF THE PROBLEM:

Students are given the freedom of choosing the topic of the project. It may be theoretical or practical and may be from any one of the following areas.

a)Physics-Theoretical
b) Physics-Practical
c) Electronics
d) Computational Physics
e)Micro Processor
f) Interdisciplinary projects involving concepts of physics

2.ARRANGEMENT OF CONTENTS:

The sequence in which the project report material should be arranged and bound should be as follows:

Cover page and Title page
Bonafide Certificate
Abstract
Table of contents
List of Tables
List of Figures
List of Symbols, Abbreviations& Nomenclature
Chapters
Appendices
References

3. PAGE DIMENSION AND BINDING SPECIFICATIONS:

The dimension of the project report should be in A4 size. The project report should be bound using flexible cover of the thick white art paper. The cover should be printed in black letters and the text for printing should be identical.

Total number of pages should not exceed 70.

4. PREPARATION FORMAT:

Cover page & Title page-A specimen copy of the cover page &Title page of the project report are given in Appendix 1.

Bonafide Certificate –The Bonafide Certificate shall be in double line spacing using Font Style Times New Roman and Font Size 14.

The Certificate shall carry the supervisor's signature and shall be followed by the supervisor's name, academic designation (not any other responsibilities of administrative nature), department and full address of the institution where the supervisor has guided the student. The term SUPERVISOR must be typed in capital letters between the supervisor's name and academic designation.

Preface- preface should be one page synopsis of project report typed double line spacing Font Style Times New Roman and Font Size 14.

Table of contents-The table of contents should list all material it as well as any material which precedes the title page and Bonafide Certificate will not find a place among the items listed in the Table of Contents but the page numbers of which are in lower case Roman letters. One and a half spacing should be adopted for typing the matter under this head.

List of Tables- The list should use exactly the same caption as they appear above the tables in the text. One and a half spacing should be adopted for typing the matter under this head. The table should be introduced in the appropriate places in the text.

List of Figures-The list should use exactly the same captions as they appear below the figures in the text. One and a half spacing should be adopted for typing the matter under this head. The figures should be introduced in the appropriate places in the text.

List of Symbols, Abbreviation & Nomenclature- One and a half spacing should be adopted for typing the matter under this head. Standard symbols, abbreviation should be used.

Chapters-The chapters may be divided into 5 parts

1. Introduction to project
2. Literature survey
3. Method and methodology/Working/ Experimental Techniques
4. Result Analysis
5. Conclusion

1. The main text will be divided into several chapters and each chapter may be further divided into several divisions and subdivisions.
2. Each chapter should be given an appropriate title.
3. Tables and figures in the chapter should be placed in the immediate vicinity of the reference where they are cited.
4. Footnotes should be sparingly. They should be typed single space and placed directly underneath in the very Same page, which refers to the materials they annotate.

Appendices- Appendices are provided to give supplementary information, which is included in the main text may serve as a distraction and cloud the central theme

1. Appendices should be numbered using numerals, Eg. Appendix 1, Appendix2 etc.
2. Appendices tables and references appearing in the Appendices should be numbered and referred to at appropriate places just as in the case of chapters.

3. Appendices shall the title of the work reported and the same title shall be made in the contents page also.

List of references: The listing of references should be typed 4 spaces below the heading "REFERENCES "in alphabetical order in single spacing left- justified. The reference material should be listed in the alphabetical order of the first author. The name of the author / authors should be immediately followed by the year and other details.

A typical illustrative list given below relates to the citation examples coated above

REFERENCES

1. Ariponnammal, S. and Natrajan, S.(1994)'transport phenomena of Sm Sel – X Asx',Pramana-journal of physics vol. 42 , No.1,pp 421-425.
2. Bernard R.W and Kellogg, C. (1980)'applications of convolution operators to problems in univalent function theory ', Michigan Mach, J., Vol.27,pp.81-94 .
3. Shin, K.G.& Mckay, N.D.(1984) "Open loop minimum time control of mechanical manipulations & its applications", Proc. Amer. Contr. Conf., San Diego, C A, pp. 1231-1236.

Tables and Figures- By the word table, is meant tabulated numerical data in the body of the project report as well as in the appendices. All other non- verbal materials used in the body of the project work and appendices such as charts , graphs, maps, photos& diagrams may be designated as figures .

5. TYPING INSTRUCTIONS

The impression on the typed copies should be black in colour.

One and a half spacing should be used for typing the general text. The general text shall be typed in the Font style "Times New Roman" & Font size 14.

Book For Reference :

1. C.R.Korthari, Research Methodology-Methods and Techniques (2nd Edition, New Age International Publishers, New Delhi(2005)

SEMESTER - III			
PRACTICAL - III C++ , MICROPROCESSOR& MICROCONTROLLER			
Code :17PPHCR3	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 4**

(Any 12 Experiment)

1. The Discrete Fourier transform
2. Currents in a network
3. Area under a curve using Monte Carlo and Simpsons rule
4. Runge Kutta solution to radioactive decay problem
5. Euler solution to two dimensional motion of a particle in a gravitational field
6. Roots of a transcendental equation
7. Curve fitting to a Gaussian, an exponential function, Cauchy's constant problem to a straight line
8. Eigen value and Eigen vectors of a matrix
9. Solution of linear harmonic oscillator and anharmonic oscillator
10. Frequency response of a series/parallel LCR Resonance circuit –Evaluation of Q-factor and bandwidth
11. AD converter using Microprocessor
12. DA converter using Microprocessor
13. Rolling Display using Microprocessor
14. Stepper motor control using Microprocessor
15. Addition, Subtraction, Multiplication and Division (using various address.. modes)
16. Data manipulation using Microprocessor (Ascending, descending, max and min)
17. Counters using Microprocessor
18. Display of any character
19. Traffic controller
20. Voltage/Temperature measurement
21. Digital clock
22. Wave form generator
23. Frequency measurement
24. Additon, Subtraction, Multiplication, Division-Microcontroller

SEMESTER - II			
Self study Paper II (Optional) Physics for Lectureship-II			
Code :17PPHSS2	**Hrs/Week: -**	**Hrs/Semester: -**	**Credits: 2**

Unit I: Mathematical Physics

Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques: root of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, Solution of first order differential equation using Runge-Kutta method. Finite difference methods. Tensors. Introductory group theory: SU(2), O(3).

Unit II :Quantum Mechanics

Wave-particle duality. Schrödinger equation (time- dependent and time independent). Eigenvalue problems (particle in a box, harmonic oscillator, etc.). Tunneling through a barrier. Wave-function in coordinate and momentum representations. Commutators and Heisenberg uncertainty principle. Dirac notation for state vectors. Motion in a central potential: orbital angular momentum, angular momentum algebra, spin, addition of angular momenta; Hydrogen atom. Stern-Gerlach experiment. Time-independent perturbation theory and applications. Variational method. Time dependent perturbation theory and Fermi's golden rule, selection rules. Identical particles, Pauli exclusion principle, spin-statistics connection.Spin-orbit coupling, fine structure. WKB approximation. Elementary theory of scattering: phase shifts, partial waves, Born approximation. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Semi-classical theory of radiation.

Unit III: Atomic & Molecular Physics

Quantum states of an electron in an atom. Electron spin. Spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, hyperfine structure and isotopic shift, width of spectrum lines, LS & JJ couplings. Zeeman, Paschen-Bach & Stark effects. Electron spin resonance. Nuclear magnetic resonance, chemicalshift. Frank-Condon principle. Born-Oppenheimer approximation. Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Lasers: spontaneous and stimulated emission, Einstein A & B coefficients. Optical pumping, population inversion, rate equation. Modes of resonators and coherence length.

Unit IV: Condensed Matter Physics

Bravais lattices. Reciprocal lattice. Diffraction and the structure factor. Bonding of solids. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, band theory of solids: metals, insulators and semiconductors. Superconductivity: type-I and type-II superconductors. Josephson junctions. Superfluidity. Defects and dislocations. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order. Quasi crystals.

Unit V: Nuclear and Particle Physics

Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotationalspectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions. Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.

Book for Study:

1. Truman’s Series UGC-CSIR JRF/NET Physical Sciences, Danika Publishing Company,New Delhi

SEMESTER - IV			
CORE X	**NANO SCIENCE AND TECHNOLOGY**		
Code :17PPCC41	**Hrs/Week: 6**	**Hrs/Semester:90**	**Credits: 4**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Recall a thorough knowledge of the basic concepts of nanoscience and nanotechnology	PSO1	R
CO 2	Explain the preparation, characterization and properties of nanomaterials	PSO4	U
CO 3	Analyze the types and properties of carbon nanotubes	PSO4	An
CO 4	Assimilate existing and new concepts, methodology and researches and apply them in their academic research environment	PSO5	E
CO 5	Aware of challenges, risks and promises of magneto electronics and nano technological development	PSO6	C
CO 6	Discuss the preparation of Quantum Nano structures	PSO1,4	U

Unit I-Introduction

History of Nanotechnology- Nano structures- importance of nano materials- Synthesis of nanomaterilas- physical methods(Laser Ablation, Evaporation,Sputtering and solvated metal Dispersion)- Chemical methods- Thermolysis, Sonochemical approach, reduction of metal ions by hydrogen and Methanol- Biosynthesis (Elementary idea only)

Unit II-Preparation and characterisation

Structural Characterisation (X- ray diffraction, Scanning Tunneling Microscopy, Atomic force microscopy) - Properties of nanomaterials(Optical,Electrical and magnetic properties) – Synthesis of semiconductor nanomaterials (Precipitation methods, Thermal decomposition of complex precursors) - Synthesis of Ceramic nanomaterials - Physical methods (Gas condensation & Laser methods)- Chemical method(Sol-gel synthesis)

Unit III- Carbon nanotube

Carbon nanotube - Carbon allotropes (Diamond ,Graphite, Carbon nanotubes) - Types of Carbon nanotubes – Graphene sheet to single walled nanotube - Synthesis of carbon nanotubes(Electric arc - Discharge method, Laser method, Fluidised bed CVD method, Solar production of Carbon nanotubes) - Purification and properties of Carbon nanotubes – Fullerenes - Purification and properties of Fullerenes.

Unit IV-Quantum well, Quantum wire and Quantum dots

Introduction - preparation of Quantum nanostructures - Fermi gas and Density of states – Calculation of the density of states in 1,2 and 3 dimension- Infrared detector -Quantum wire(Production ,Structure, Use), Quantum dot-Fabrication Techniques - Application of Quantum dots – Quantum dot information storage, Infrared photodetectors, Lasers.

Unit V-Magneto electronics and Applications of Nanotechnology

Magneto electronics: Nano crystalline soft magnetic materials-Permanent magnetic materials-Theoritical background-Super para magnetism-Coulomb blockade-Single electron transistor-Spintronics-Giant magneto resistance-Quantum Hall Effect-fractional Quantum Hall Effect

Applications of Nanotechnology:Chemistry and Environment - Energy applications of Nanotechnology -Information and Communication- Heavy industry - Consumer goods - Nano medicine - medical applications of molecular nanotechnology (Nanorobots, Cell repair machines, nanonephrology)

Book for Study:

1.Nano Physics, Dr.Sr.GeraldinJayam

Unit	Book no.	Page No
III	1	2.1-2.7,2.14-2.20,2.26-2.29
IV	1	4.1-4.10,4.15-4.30
V	1	5.1-5.5,5.10-5.30

Book for Reference

1. Shanmugam.S, Nanotechnology, MJP Publishers, Chennai(2011)
2. Parthasarathy. B.K, Nanostructure and Nanomaterials, Isha Books, Delhi(2007)
3. Fahrner.W.R (Ed), Nanotechnology and Nanoelectronics- materials, Devices, measurement techniques, Spinger(2004)
4. Charles.P. Poole Jr Frank J. Owens;John Wiley & Sons inc.Publication(2003)
5. Massimiliano Di ventra, Stephane Evoy, James R. Heflin Jr(Editors) , Introduction to Nanoscale science and Technology Springer(2009)
6. Guozhong Cao, Nanostructures and Nanomaterials – Synthesis, Properties and Applications, Imperial College Press, London(2004).

SEMESTER - IV			
CORE XI	**QUANTUM MECHANICS –II**		
Code :17PPHC41	**Hrs/Week: 6**	**Hrs/Semester:90**	**Credits: 4**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Understand time dependent perturbation theory in quantum mechanics	PSO1	U
CO 2	Interpret the wave functions and apply operators to its to obtain information about the particle's physical properties	PSO2	U
CO 3	Develop a knowledge and understand the scattering matrix and partial analysis	PSO1	A
CO 4	Relate the Einstein Coefficient using semi classical treatment	PSO6	R
CO 5	Interpret the form and construction of relativistic wave equations	PSO6	U
CO 6	Discuss the construction of Symmetric and anti-symmetric wave functions	PSO1	U

Unit I: Time Evaluation Process

Time dependent perturbation theory – first & second order – Application: Elastic scattering (first order) – Harmonic perturbation - Transition probability – The selection rules – Application: Elastic scattering (First order) - Adiabatic & Sudden approximations – Disturbance of an oscillator.

Unit II: Identical Particles and Spin

Symmetric and antisymmetric wavefunctions – construction – The exclusion principle – spin matrices and eigen functions – Collision of identity particles – Expectation value and projection operator – Density operator – Equation of motion - Density matrix.

Unit III: Scattering Theory

Definition and interpretation of scattering cross section – Quantum theory of scattering – Green's function – The Born approximation and its validity – Scattering by Yukawa potential – Ramsauer – Townsend effect – Scattering by a perfect rigid sphere - Scattering by a square well potential – Resonance scattering – Couloumb potential.

Unit IV:Semiclassical Treatment

Absorption and induced emission – Transition probability – Electric dipole transition – Einstein coefficient – Relation between Einstein coefficients – Selection rules for a single particle – Photoelectric effect.

Unit V: Relativistic Wave Equations

The Klein-Gordan equation – The Dirac equation – Dirac matrices – Free particle solutions - The electron in an electromagnetic field – spin angular momentum – spin orbit energy – The hydrogen atom – Classification of energy levels – Negative energy states.

Books for study:

1.L.I.Schiff, Quantum Mechanics , IIIEdition,McGraw Hill,1968

2. Ajoy Ghatak, S.Lokanathan, Quantum Mechanics Theory and Applications, 5th Edition, Macmillan India Ltd, NewDelhi.

3. Quantum Mechanics ,Chatwal Anand, Fourth Edition,1993,Himalaya Publishing house,Bombay,

4.P.M.Mathews and K.Vengatesan, A text book of Quantum Mechanics, 38 reprint 2007, Tata

Mc Graw Hill Publishing Company Ltd, NewDelhi.

Unit	Book no.	Sections / Page No
I	4	335 – 345, 351 – 354
	2	594 – 598
	1	289 – 291, 292 -295
II	1	362 – 366, 368, 372 – 374, 378 – 383
	4	381 - 383
III	2	552 – 560, 574 - 578
	1	324 – 326, 123 - 129
IV	1	398 , 401 – 406, 416 – 417, 420 - 422
	2	227 - 228
V	1	466 - 488

Books for Reference:

1. Richard L.Liboff , Introductory Quantum mechanics, Fourth edition, Pearson Education 2003
2. SathyaPrakash, Advanced Quantum Mechanics, Reprint 2013,Kedar Nath and Ram Nath Publications, Meerut.
3. P.M.Mathews and K.Vengatesan, A text book of Quantum Mechanics, 38 reprint 2007, Tata Mc Graw Hill Publishing Company Ltd, NewDelhi.
4. S.N.Biswas, Quantum Mechanics, 2011 Reprint, Books and Allied P Ltd, Kolkata.
5. Ajoy Ghatak, S.Lokanathan, Quantum Mechanics Theory and Applications, 5th Edition, Macmillan India Ltd, NewDelhi.
6. Vimal Kumar Jain, Introduction to Quantum Mechanics, 2010 Edition, Narosa publishing P Ltd, NewDelhi.

SEMESTER - IV			
CORE XII ATOMIC AND MOLECULAR SPECTROSCOPY			
Code :17PPHC42	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 4**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Explain the structure of atoms and the origin of the observed spectra	PSO1	U
CO 2	Interpret rotational spectra, get information about molecular dimension and atomic masses	PSO4	U
CO 3	Explain pure rotational Raman spectra and understand the techniques in instrumentation	PSO3	U
CO 4	Apply knowledge of Mossbauer spectroscopy in solid state physics and nanotechnology	PSO4	A
CO 5	Assess how nuclear spins are affected by magnetic field and able to explain what happens when radio frequency radiation is observed	PSO1	E
CO 6	Discuss the techniques of ESR spectroscopy	PSO1	U

Unit I: Atomic Spectra

Introduction-Different Spectral lines of hydrogen-Origin of Atomic Spectra: Rutherford's explanation-Bohr's theory of Hydrogen Spectrum-Critical potential (excitation & ionization potentials)-vector atom model.

Electronic Spectroscopy: Structure of atoms-electronic angular momentum-The angular momentum of many –electron atoms-The Zeeman effect

Unit II: Microwave Spectroscopy

Microwave Spectroscopy: The rotation of molecules – Rotational spectra – Diatomic molecules – Polyatomic molecules –Techniques and instrumentation –Chemical analysis. Applications(Microwave oven)

Unit III:Infra-Red Spectroscopy and Raman Spectroscopy

Infra Red Spectroscopy: The vibrating diatomic molecule – The Diatomic vibrating rotator- The interactions of rotations and vibrations- The vibrations of polyatomic molecules- Techniques and instrumentations.

Raman spectroscopy: Pure rotational Raman Spectra- vibrational Raman spectra- Techniques and instrumentation.

Unit IV: Electronic Spectroscopy of Molecules and Mossbauer Spectroscopy

Vibrational coarse structure: progressions – intensity of vibrational electronic spectra: The Frank – Condon principle – Dissociation energy and Dissociation products – rotational fine structure of electronic- vibration transition.

Mossobaur Spectroscopy: Principles of Mossbauer-Applications of Mossbauer Spectroscopy

Unit V: Resonance Spectroscopy

NMR – Chemical shift – The coupling constant – Nuclear quadrupole effects – Techniques and instrumentation.

ESR – The hyperfine structure – Double resonance – Fine structure - Techniques of ESR spectroscopy.

Books for study:

1. M.K.Dutta, Atomic and Molecular Spectroscopy, Ist Edition 2010, IVY Publishing House, Delhi.
2.C.N.Banwell, Fundamentals of Molecular spectroscopy, 4th Edition,Tata McGraw hill Publishing Company, NewDelhi.

Unit	Book No.	Sections
I	1 2	1-4 5.1,5.2,5.4,5.6
II	2	2.1-2.7
III	2	3.1,3.2,3.4,3.5,3.8,4.2,4.3,4.6
IV	2	6.1.2-6.1.5,9.1,9.2
V	2	7.2, 7.2.1 - 7.2.2,7.3.4,7.4,7.5.1,7.5.3-7.5.6

Books for Reference:

1.G.M.Barrow, Introduction to Molecular Spectroscopy, 17thprint, MGH Publishing Company.
2. Gary M.Lampman, Donald L.Pavaia, George S.Keiz, James R.Vyvyan, Spectroscopy, 4th Edition, Cengage Learning India P Ltd, Delhi.
3.G.Aruldhas, Molecular structure & Spectroscopy, Second edition,Prentice hall Private Ltd.
4.Suresh Chandra, Molecular Spectroscopy, Narosa Publishing House Ltd, Newdelhi.

SEMESTER - IV			
ELECTIVE - III	**CONDENSED MATTER PHYSICS**		
Code :17PPHE41	**Hrs/Week: 6**	**Hrs/Semester: 90**	**Credits: 5**

Course Outcomes

CO No.	Upon completion of this course, students will be able to	PSOs addressed	CL
CO 1	Recall about the crystal structure and degree of ordering to atom binding and packing	PSO1	R
CO 2	Explain the physics of different types of bonds in crystalline structure	PSO6	U
CO 3	Classify condensed matter upon its degree of order with emphasis on scattering experiments	PSO3	U
CO 4	Explain the effective electron mass and apply it to describe electron dynamics in semiconductors	PSO5	U
CO 5	Develop the knowledge of magnetism to explain natural physical process and related technological advances	PSO6	A
CO 6	Calculate the intrinsic carrier concentration of semiconductor crystals	PSO1	A

Unit I: Crystal Structure

Periodic arrays of atoms-Fundamental types of lattice –Index systems for crystal planes- Simple crystals structures - Non ideal crystal structure-Reciprocal lattice vectors-Diffraction conditions-Brillouin zones-Fourier analysis of the basis.

Unit II: Crystal binding and Elastic constants

Crystals of inert gases-Ionic crystals-Covalent crystals-metals-hydrogen bonds-atomic radii-analysis of elastic strains-elastic compliance and stiffness constants-elastic waves in cubic crystals

Unit III: Crystal vibrations

Vibrations of crystals with monatomic basis - Two atoms per primitive basis -Quantization of elastic waves - Phonon momentum – Inelastic scattering by phonons

Unit IV: Semiconductor Crystals

Band gap-equations of motions-intrinsic carrier concentration-impurity conductivity-thermo electric effects-semimetals-superlattices

Unit V: Magnetism

Langevin dia magnetism equation-Quantum theory of dia magnetism of mono nuclear systems-para magnetism-Quantum theory of para magnetism-Ferro magnetic order-magnons-ferrimagnetic order-anti ferro magnetic order-ferromagnetic domain

Books for study:

1.Charles Kittel, Introduction to Solid state Physics, Wiley, 7th Edition, 1995.

Unit	Book No.	Page Number
I	1	1-19,29-42
II	1	47-85
III	1	89-102
IV	1	185-218
V	1	297-311,323-352

Books for Reference:

1. L. V. Azaroff, Introduction to Solids (McGraw Hill), 9th Reprint, Newyork.
2.P.K.palanisamy, Solid State Physics, 2013 Reprint, Scitech publications Private Ltd, Chennai.
3. H.C.Gupta , Solid State Physics, II Edition, Vikas Publishing home Ltd, Noida.
4. R.L.Singhal, Solid State Physics, Kedar Nath and Ram Nath publishers, Meerut.

SEMESTER - IV			
PRACTICAL I V	**ELECTRONICS -II**		
Code : 17PPHCR4	**Hrs/Week:- 6**	**Hrs/Semester:- 90**	**Credits:4**

(Any 12 Experiments)

1. OP-AMP: Basic circuit design
2. Wien's Bridge oscillator OP-AMP
3. FET amplifier design(Compulsary)
4. OP-AMP parameter calculation
5. Power amplifier: Transistor and IC
6. Design of synchronous counter
7. Digital comparator IC based
8. Schmitt trigger
9. Code converter
10. De Morgan's Laws verification
11. Parity Checker/generator and comparator by gates
12. Op-amp: I to V,V to I & square wave
13. Op-amp: Phase shift operator
14. Op-amp: Solving I order simultaneous equations
15. Construction of circuits using PCB