B. SC. (HONOURS) PHYSICS

DISCIPLINE SPECIFIC CORE COURSE – DSC - 13: ELECTROMAGNETIC THEORY

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Electromagnetic Theory DSC – 13	4	3	0	1	Class XII pass with Physics and Mathematics as main subjects	Mathematical Physics I, II; Waves and Oscillation; Electricity and Magnetism papers of this course or their equivalents

LEARNING OBJECTIVES

This core course develops further the concepts learnt in the electricity and magnetism course to understand the properties of electromagnetic waves in vacuum and different media.

LEARNING OUTCOMES

At the end of this course the student will be able to,

- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density
- Understand electromagnetic wave propagation in unbounded media: Vacuum, dielectric medium, conducting medium, plasma
- Understand electromagnetic wave propagation in bounded media: reflection and transmission coefficients at plane interface in bounded media
- Understand polarization of electromagnetic waves: Linear, circular and elliptical polarization. Production as well as detection of waves in laboratory
- Learn the features of planar optical wave guide
- In the laboratory course, the students will get an opportunity to perform experiments with polarimeter, Babinet compensator, ultrasonic grating and simple dipole antenna. Also, to study phenomena of interference, refraction, diffraction and polarization

SYLLABUS OF DSC – 13

THEORY COMPONENT

Unit - I **(6 Hours)**

Review of Maxwell's equations; Coulomb gauge and Lorentz gauge; Poynting's theorem and Poynting's vector; electromagnetic (em) energy density; physical concept of electromagnetic field energy density

Unit – II **(10 Hours)**

EM wave propagation in unbounded media: Plane em waves through vacuum and isotropic dielectric medium: transverse nature, refractive index, dielectric constant, wave impedance. Plane em waves through conducting medium: relaxation time, skin depth, attenuation constant;

Wave propagation through dilute plasma: electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth.

Unit – III **(9 Hours)**

EM waves in bounded media: Boundary conditions at a plane interface between two media; reflection and refraction of plane em waves at plane interface between two dielectric media - Laws of reflection and refraction; Fresnel's formulae for perpendicular and parallel polarization, Brewster's law; reflection and transmission coefficients; total internal reflection, evanescent waves; metallic reflection (normal incidence)

Unit – IV **(13 Hours)**

Polarization of EM waves: Propagation of em waves in an anisotropic media; symmetric nature of dielectric tensor; Fresnel's formula; uniaxial and biaxial crystals; light propagation in uniaxial crystal; double refraction; polarization by double refraction; Nicol prism; ordinary and extraordinary refractive indices; production and detection of plane, circular and elliptically polarized light; phase retardation plates: quarter wave and half wave plates

Optical rotation; Biot's laws for rotatory polarization; Fresnel's theory of optical rotation; specific rotation

Unit – V **(7 Hours)**

Wave guides: Planar optical wave guides; planar dielectric wave guide ($-d/2 < x < d/2$); condition of continuity at interface; phase shift on total reflection; Eigenvalue equations; phase and group velocity of guided waves; field energy and power transmission (TE mode only)

References:

Essential Readings:

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd edition, 1998, Benjamin Cummings.
2) Electromagnetic Field and Waves, P. Lorrain and D. Corson, 2nd edition, 2003, CBS Publisher
3) Classical Electrodynamics, J. D. Jackson, 3rd edition, 2010, Wiley
4) Principle of Optics, M. Born and E. Wolf, 6th edition, 1980, Pergamon Press
5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi

Additional Readings:

1) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan, and S. R. Choudhary, 2017, TMH
2) Principles of Electromagnetic Theory, C. Jain, 2017, Narosa Publishing House
3) Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
4) Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
5) Problems and solution in Electromagnetics, A. Ghatak, K. Thyagarajan and Ravi Varshney, 2015
6) Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning
7) Engineering Electromagnetic, W. H. Hayt, 8th edition, 2012, McGraw Hill.
8) Electromagnetics, J. A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
9) 2008+ Solved Problems in Electromagnetics, S. A. Nasar, 2001, SciTech

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

- Mandatory sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the lab, including necessary precautions.
- Mandatory sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

<u>At least six experiments to be performed from the following list</u>

1) To verify the law of Malus for plane polarized light.
2) To determine the specific rotation of sugar solution using polarimeter.
3) To analyse elliptically polarized light by using a Babinet's compensator.
4) To study the elliptical polarized light using Fresnel rhomb.
5) To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6) To study the reflection and refraction of microwaves
7) To study polarization and double slit interference in microwaves.
8) To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9) To determine the refractive index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10) To verify the Stefan's law of radiation and to determine Stefan's constant.
11) To determine Boltzmann constant using V-I characteristics of PN junction diode.
12) To find numerical aperture of an optical fibre.
13) To use a prism shaped double refracting crystal to determine the refractive indices of the quartz/ calcite corresponding to ordinary and extra-ordinary rays.
14) To measure birefringence of Mica
15) To determine the dielectric constant of solids using microwaves

References for laboratory work:

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House
2) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publisher
3) Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
4) Practical Physics, G. L. Squires, 4th edition, 2015, Cambridge University Press
5) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd

DISCIPLINE SPECIFIC CORE COURSE – DSC - 14: QUANTUM MECHANICS – I

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Quantum Mechanics – I DSC – 14	4	3	0	1	Class XII pass with Physics and Mathematics as main subjects	Light and Matter, and Elements of Modern Physics papers of this course or their equivalents

LEARNING OBJECTIVES

The development of quantum mechanics has revolutionized the human life. In this course, the students will be exposed to the probabilistic concepts of basic non-relativistic quantum mechanics and its applications to understand the sub atomic world.

LEARNING OUTCOMES

After completing this course, the students will be able to,

- Understand the applications of the Schrodinger equation to different cases of potentials namely finite square potential well, harmonic oscillator potential.
- Solve the Schrodinger equation in 3-D.
- Understand the spectrum and eigen functions for hydrogen atom
- Understand the angular momentum operators in position space, their commutators, eigenvalues and eigen functions.
- In the laboratory course, the students will be able to use computational methods to
  - Solve Schrödinger equation for ground state energy and wave functions of various simple quantum mechanical one- dimensional potentials
  - Solve Schrödinger equation for ground state energy and radial wave functions of some central potentials

SYLLABUS OF DSC - 14

THEORY COMPONENT

Unit – I (10 Hours)

General discussion of bound states in an arbitrary potential: Continuity of wave function, boundary conditions and emergence of discrete energy levels. Application to energy eigen states for a particle in a finite square potential well, Momentum space wavefunction, Time evolution of Gaussian Wave packet, Superposition Principle, linearity of Schrodinger Equation, General solution as a linear combination of discrete stationary states, Observables as operators, Commutator of position and momentum operators, Ehrenfest's theorem.

Unit – II (8 Hours)

Harmonic oscillator: Energy eigen values and eigen states of a 1-D harmonic oscillator using algebraic method (ladder operators) and using Hermite polynomials. Zero point energy and uncertainty principle.

Unit – III **(15 Hours)**

Schrödinger Equation in three dimensions: Probability and probability densities in 3D. Schrödinger equation in spherical polar coordinates, its solution for Hydrogen atom solution using separation of angular and radial variables, Angular momentum operator, quantum numbers and spherical harmonics. Radial wave functions from Frobenius method; shapes of the probability densities for ground and first excited states; Orbital angular momentum quantum numbers l and m_l, s, p, d shells.

Unit – IV **(12 Hours)**

Angular momentum: Commutation relations of angular momentum operators; concept of spin and total angular momentum; ladder operators, eigenvalues, eigenvectors; Pauli matrices; addition of angular momenta

References:

Essential Readings:

1) Quantum Mechanics: Theory and Applications, A. Ghatak and S. Lokanathan, 6th edition, 2019, Laxmi Publications, New Delhi.
2) Introduction to Quantum Mechanics, D. J. Griffith, 2nd edition, 2005, Pearson Education.
3) A Text book of Quantum Mechanics, P. M. Mathews and K. Venkatesan, 2nd edition, 2010, McGraw Hill.
4) Quantum Mechanics, B. H. Bransden and C. J. Joachain, 2nd edition, 2000, Prentice Hall
5) Quantum Mechanics: Concepts and Applications, 2nd edition, N. Zettili, A John Wiley and Sons, Ltd., Publication
6) Atomic Physics, S. N. Ghoshal, 2010, S. Chand and Company

Additional Readings:

1) Quantum Mechanics for Scientists & Engineers, D. A. B. Miller, 2008, Cambridge University Press.
2) Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, 1966, Addison-Wesley Publications
3) Quantum Mechanics, L. I. Schiff, 3rd edition, 2010, Tata McGraw Hill.
4) Quantum Mechanics, R. Eisberg and R. Resnick, 2nd edition, 2002, Wiley
5) Quantum Mechanics, B. C. Reed, 2008, Jones and Bartlett Learning.
6) Quantum Mechanics, W. Greiner, 4th edition, 2001, Springer.
7) Introductory Quantum Mechanics, R. L. Liboff, 4th edition, 2003, Addison Wesley

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

At least 4 programs must be attempted. The implementation may be done in C++/Scilab /Python. Use of available library functions may be encouraged. Similar programs may be added.

Unit 1

1) Visualize the spherical harmonics by plotting the probability density for various values of the quantum numbers (*l, m*)

2) Use the analytical solution for a particle in finite potential well. Numerically solve the transcendental equation one gets after putting the continuity and boundary conditions to determine the energy eigenvalues for various values of the potential width and depth. Plot the corresponding normalised eigen functions.

Unit 2

Solve the Schrödinger equation using shooting/finite difference or any other method for the following simple 1-D potentials and compare with the analytical solutions:

1) Particle in a box
2) Particle in a finite potential well
3) Harmonic Potential

Unit 3

Solve the s-wave Schrodinger equation for the following cases.

$$\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E],$$

1) Ground state and the first excited state of the hydrogen atom:

$$V(r) = \frac{-e^2}{r}$$

Here *m* is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 $(\text{eVÅ})^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511x10^6 eV/c^2.

2) For an atom in the screened coulamb potential

$$V(r) = \frac{-e^2}{r} e^{\frac{-r}{a}}$$

Here *m* is the reduced mass of the system (which can be chosen to be the mass of an electron). Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 $(\text{eVÅ})^{1/2}$, *m* = 0.511x10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

Unit 4

Solve the s-wave Schrodinger equation $\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$, for a particle of mass *m* for the following cases

1) Anharmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose *m* = 940 MeV/c^2, *k* = 100 MeV fm^{-2}, *b*= 0, 10, 30 MeV fm^{-3}. In these units, $c\hbar$ = 197.3 MeV fm. The ground state energy is expected to lie between 90 and 110 MeV for all three cases.

2) For the vibrations of hydrogen molecule with Morse potential

$$V(r) = D(e^{-2ar'} - e^{-ar'}), r' = \frac{r - r_0}{r}$$

Here m is the reduced mass of the two-atom system for the Morse potential

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: $m = 940 \times 10^6$ eV/c^2, $D = 0.755501$ eV, $\alpha = 1.44$, $r_0 = 0.131349$ Å

References for laboratory work:

1) Schaum's Outline of Programming with C++, J. Hubbard, 2000, McGraw-Hill Education.
2) C++ How to Program, P. J. Deitel and Harvey Deitel, 2016, Pearson
3) Scilab (A Free Software to Matlab): H. Ramchandran, A. S. Nair, 2011, S. Chand and Co
4) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
5) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
6) Computational Physics, Darren Walker, 1st edition, 2015, Scientific International Pvt. Ltd
7) An Introduction to Computational Physics, T. Pang, 2010, Cambridge University Press
8) A Guide to MATLAB, B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, 3rd edition, 2014, Cambridge University Press

DISCIPLINE SPECIFIC CORE COURSE – DSC - 15: DIGITAL ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Digital Electronics DSC – 15	**4**	**3**	**0**	**1**	Class XII pass with Physics and Mathematics as main subjects	NIL

LEARNING OBJECTIVES

The objective of the course is to introduce digital electronics and its simple applications to physics Honours students. The course is designed to familiarize the students with the different number systems (binary, octal and hexadecimal), laws of Boolean algebra, logic gates and combinational and sequential logic circuits utilised in designing counters and registers.

LEARNING OUTCOMES

This paper is one of the core papers in the Physics curriculum. After studying this paper students will become familiar with,

- Digital signals, positive and negative logic, Boolean variables, truth table, various number system codes and their inter-conversions.
- Students will be able to learn to minimise a given Boolean function using laws of Boolean algebra and Karnaugh map to minimise the hardware requirement of digital logic circuits.
- Understand the working principle of data processing circuits, arithmetic circuits, sequential logic circuits, registers, counters based on flip flops

SYLLABUS OF DSC - 15

THEORY COMPONENT

Unit – I - Integrated circuits (2 Hours)

Integrated Circuits (Qualitative treatment only), active and passive components, discrete components, wafer, chip, advantages and drawbacks of ICs, scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only), classification of ICs, examples of linear and digital lCs

Unit – II - Digital circuits and Boolean algebra (14 Hours)

Difference between analog and digital circuits, binary number, decimal to binary and binary to decimal conversion, BCD, octal and hexadecimal numbers, AND, OR and NOT gates (realization using diodes and transistor), NAND and NOR gates as universal gates, XOR and XNOR gates and application as parity checkers

De Morgan's theorems, Boolean laws, simplification of logic circuit using Boolean algebra, fundamental products, idea of minterms and maxterms, conversion of truth table into equivalent logic circuit by (1) Sum of Products method and (2) Karnaugh map simplification (upto four variables).

Unit – III - Combinational Logic Circuits (9 Hours)

Data processing circuits: Multiplexers and its applications, de-multiplexers, decoders, encoders Arithmetic logic circuits: Express binary number in signed and unsigned form, 1's and 2's complement representation, binary addition, binary subtraction using 2's complement, half and full Adders, half and full subtractors, 4-bit binary adder/subtractor using 2's complement method.

Unit – IV - Sequential Logic Circuits (8 Hours)

Flip Flops SR, D, and JK clocked (level and edge triggered) flip-flops, preset and clear operations, race-around conditions in JK flip-flop, master-slave JK flip-flop, conversion of one flip flop to another using an excitation table

Unit – V - Application of Sequential Logic Circuits (9 Hours)

Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

Counters: Asynchronous counters, MOD-N synchronous counter designing using excitation table.

Unit – VI – Timers (3 Hours)

IC 555: Pin -out diagram, block diagram and its applications as astable multivibrator and monostable multivibrator

References:

Essential Readings:

1) Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th edition, 2011, Tata McGraw
2) Fundamentals of Digital Circuits, A. Kumar, 2nd edition, 2009, PHI Learning Pvt. Ltd.
3) Digital Fundamentals, T. L. Floyd, 1994, Pearson Education Asia
4) Digital Principles and Applications, D. P. Leach and A. P. Malvino, 1995, Tata McGraw Hill
5) Digital Design, M. M. Mano and M. D. Ciletti, 2007, Pearson Education Asia
6) Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
7) Digital Electronics G. K. Kharate, 2010, Oxford University Press

Additional Readings:

1) Logic circuit design, S. P. Vingron, 2012, Springer
2) Digital Principles, R. L. Tokheim, 1994, Schaum's Outline Series, Tata McGraw-Hill
3) Solved Problems in Digital Electronics, S. P. Bali, 2005, Sigma Series, Tata McGraw-Hill
4) Digital Electronics: An Introduction To Theory And Practice, W. H. Gothmann, 2000, Prentice Hall of India
5) Modern Digital Electronics, R. P. Jain, 2003, Tata McGraw-Hill
6) Digital Electronics, S. Ghoshal, 2012, Cengage Learning
7) Digital Electronics, S. K. Mandal, 2010, 1st edition, McGraw Hill

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

At least five experiments should be performed from the following list.
All designing should be done on the bread boards.

1) (a) To design a combinational logic system for a specified truth table.
   (b) To convert Boolean expression into logic circuit and design it using basic logic gate ICs
2) To minimize a given logic circuit using K-map and design using NAND gates.
3) Designing of Half Adder and Half Subtractor using NAND gates
4) Designing of 4-bit binary adder using adder IC.
5) To build Flip-Flop (RS, Clocked RS) circuits using NAND gates.
6) To build Flip-Flop (D-type and JK) circuits using NAND gate
7) To build a 3-bit Counter using D-type/JK Flip-Flop ICs and study timing diagrams.
8) To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
9) To design an astable multivibrator of given specifications using 555 Timer.

References for laboratory work:

1) Digital Fundamentals, T. L. Floyd, 1994, Pearson Education Asia
2) Digital Principles and Applications, D. P. Leach and A. P. Malvino, 1995, Tata McGraw Hill
3) Digital Design, M. M. Mano and M. D. Ciletti, 2007, Pearson Education Asia
4) Digital Circuits and Systems, Venugopal, 2011, Tata McGraw Hill