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DEPARTMENT OF PHYSICS AND ASTROPHYSICS SEMESTER – II

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**DISCIPLINE SPECIFIC CORE COURSE – 4:
MATHEMATICAL PHYSICS II**

Course title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Mathematical Physics II DSC – 4	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Should have studied DSC-1 - Mathematical Physics I of this program or its equivalent

LEARNING OBJECTIVES

The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Use curvilinear coordinates to solve problems with spherical and cylindrical symmetries
- Represent a periodic function by a sum of harmonics using Fourier series
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method
- Understand the properties and applications of Legendre polynomials
- Learn about gamma and beta functions and their applications
- In the laboratory course, the students will learn to
 - Apply appropriate numerical method to solve selected physics problems both using user defined and in-built functions from Scilab/ Python
 - Solve non-linear equations
 - Perform least square fitting of the data taken in physics lab by user defined functions.
 - Interpolate a data by polynomial approximations
 - Generate and plot a function by its series representation
 - Generate and plot Legendre polynomials and verify their properties.
 - Numerically integrate a function and solve first order initial value problems numerically.

SYLLABUS OF DSC – 4

THEORY COMPONENT

UNIT – I (6.5 Weeks)

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Scale factors, element of area and volume in spherical and cylindrical coordinate Systems. Derivation of Gradient, Divergence, Curl and Laplacian in Spherical and Cylindrical Coordinate Systems
Fourier Series: Periodic functions, Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only), Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients, Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series), Parseval's Identity.

UNIT – II (8.5 Weeks)

Frobenius Method and series solution of Differential Equations: Singular Points of Second Order Linear Differential Equations and their importance, Frobenius method for finding series solution and its applications, Legendre Differential Equations and its solution. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality of Legendre Polynomials, Simple recurrence relations, Expansion of function in a series of Legendre Polynomials.

Some Special Integrals: Beta and Gamma Functions and relation between them, Expression of Integrals in terms of Gamma and Beta Functions.

References:

Essential Readings:

- 1) Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book.
- 2) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
- 3) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge Univ. Press.
- 4) Vector Analysis and Cartesian Tensors, D. E. Bourne and P. C. Kendall, 3 Ed., 2017, CRC Press.
- 5) Vector Analysis, Murray Spiegel, 2nd Ed., 2017, Schaum's Outlines Series.
- 6) Fourier analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
- 7) Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
- 8) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 7 Ed., 2013, Elsevier.

Additional Readings:

- 1) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.
- 2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.

- 3) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
- 4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.
- 5) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
- 6) Mathematical Physics, A. K. Ghatak, I. C. Goyal and S. J. Chua, 2017, Laxmi Publications Private Limited.

PRACTICAL COMPONENT

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem.

- Every student must perform at least 12 programs covering each unit.
- The list of recommended programs is suggestive only. Students should be encouraged to do more practice. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.
- The implementation can be either in Python/ C++/ Scilab.

Unit 1: Root Finding: Bisection, Newton Raphson and secant methods for solving roots of equations, Convergence analysis.

Recommended List of Programs (At least two):

- (a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
- (b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
- (c) To approximate nth root of a number up to a given number of significant digits.

Unit 2: Least Square fitting (At least one): Algorithm for least square fitting and its relation to maximum likelihood for normally distributed data.

- a) Make a function for least square fitting, use it for fitting given data (x, y) and estimate the parameters a, b as well as uncertainties in the parameters for the following cases.
 - i. Linear ($y = ax + b$)
 - ii. Power law ($y = ax^b$)
 - iii. Exponential ($y = ae^{bx}$)
- b) Weighted least square fitting of given data (x, y) with known error/uncertainty-values using user defined function.

Unit 3: Generating and plotting of a function using series representation (At least one):

- a) To approximate the elementary functions (e.g. $\exp(x)$, $\sin(x)$, $\cos(x)$, $\ln(1+x)$, etc.) by a finite number of terms of Taylor's series and discuss the truncation error. To plot the function as well the nth partial sum of its series for various values of n on the same graph and visualise the convergence of series.
- b) Generating and plotting Legendre Polynomials using series expansion and verifying recurrence relation

Unit 4: Interpolation: Concept of Interpolation, Lagrange form of interpolating polynomial, Error estimation, optimal points for interpolation.

Recommended List of Programs (At least one)

- (a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i, y_i) and use this polynomial to find the value of y at a value of x not included in the data.
- (b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function $f(x)$ and use it to interpolate at a value of x not used in table.

Unit 5: Numerical Integration: Newton Cotes Integration methods (Trapezoidal and Simpson rules) for definite integrals, derivation of composite formulae for these methods and discussion of error estimation.

Recommended List of Programs (At least three)

- (a) Given acceleration at equidistant time values, calculate position and velocity and plot them.
- (b) Use integral definition of $\ln(x)$ to compute and plot $\ln(x)$ in a given range. Use trapezoidal, Simpson and Gauss quadrature methods and compare the results.
- (c) Verify the rate of convergence of the composite Trapezoidal and Simpson methods by approximating the value of a given definite integral.
- (d) Verify the Orthogonality of Legendre Polynomials.
- (e) To evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier etc.). To plot the function as well the n th partial sum of its series for various values of n on the same graph and visualise the convergence of series. Study of Gibbs phenomenon.
- (f) Verify the properties of Dirac Delta function using its representation as a sequence of functions.

Unit 6: Numerical Solutions of Ordinary Differential Equations: Euler, modified Euler, and Runge-Kutta (RK) second and fourth order methods for solving first order initial value problems (IVP) and system of first order differential equations,

Recommended List of Programs (At least two)

- (a) Solve given first order differential equation (Initial value problems) numerically using Euler RK2 and RK4 methods and apply to the following physics problems:
 - i. Radioactive decay
 - ii. Current in RC and LR circuits with DC source
 - iii. Newton's law of cooling
- (b) Write a code to compare the errors in various numerical methods learnt by solving a first order IVP with known solution.
- (c) Solve a system of first order IVP numerically using Euler and Runge-Kutta methods. Application to physical problems.

References (for Laboratory work):

- 1) Documentation at the Python home page (<https://docs.python.org/3/>) and the tutorials there (<https://docs.python.org/3/tutorial/>).

- 2) Documentation of NumPy and Matplotlib: <https://numpy.org/doc/stable/user/> and <https://matplotlib.org/stable/tutorials/>
- 3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
- 4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
- 5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
- 6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
- 7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
- 8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
- 9) Computational Problems for Physics, R. H. Landau and M. J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

**DISCIPLINE SPECIFIC CORE COURSE – 5:
ELECTRICITY AND MAGNETISM**

Course title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Electricity and Magnetism DSC – 5	4	3	0	1	Class XII pass with Physics and Mathematics as main subjects	Physics and Mathematics syllabus of class XII

LEARNING OBJECTIVES

This course reviews the concepts of electromagnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course covers static and dynamic electric and magnetic fields due to continuous charge and current distributions respectively.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Apply Coulomb's law to line, surface, and volume distribution of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Solve boundary value problems using method of images
- Understand the concept of electric polarization and bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and magnetic susceptibility in magnetic materials
- Understand the impact of time-varying magnetic and electric fields in order to comprehend the formulation of Maxwell's equations.

SYLLABUS OF DSC – 5

THEORY COMPONENT

UNIT – I (5 Weeks)

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge, Divergence of electric field using the Dirac Delta function, Curl of electric field, Electric field vector as negative gradient of scalar potential, Ambiguities of electric potential, Differential and integral forms of Gauss's Law, Application of Gauss's law to various charge distributions having spherical, cylindrical and planar symmetries.

Boundary Value Problems in Electrostatics: Formulation of Laplace's and Poisson equations, First and second uniqueness theorems, Solutions of Laplace and Poisson equations in one dimension using spherical and cylindrical coordinate systems and solutions in three-dimensional using Cartesian coordinates applying separable variable technique, Electrostatic boundary conditions for conductors and capacitors.

UNIT – II (3.67 Weeks)

Special techniques for the calculation of Potential and Field: The Method of Images is applied to a system of a point charge and finite continuous charge distribution (line charge and surface charge) in the presence of (i) a plane infinite sheet maintained at constant potential, and (ii) a sphere maintained at constant potential.

Electric Field in Matter: Polarization in matter, Bound charges and their physical interpretation, Field inside a dielectric, Displacement vector **D**, Gauss' law in the presence of dielectrics, Boundary conditions for **D**, Linear dielectrics, electric susceptibility and dielectric constant, Idea of complex dielectric constant due to varying electric field, Boundary value problems with linear dielectrics

UNIT – III (6.33 Weeks)

Magnetic Field: Divergence and curl of magnetic field **B**, Magnetic field due to arbitrary current distribution using Biot-Savart law, Integral and differential forms of Ampere's law, Vector potential and its ambiguities, Coulomb gauge and possibility of making vector potential divergence less, Vector potential due to line, surface and volume currents using Poisson equations for components of vector potential.

Magnetic Properties of Matter: Magnetization vector, Bound currents, Magnetic intensity, Differential and integral form of Ampere's Law in the presence of magnetised materials, Magnetic susceptibility and permeability of diamagnetic, paramagnetic and ferromagnetic materials.

Electrodynamics: Faraday's law, Lenz's law, Inductance and electromotive force, Ohm's law ($\vec{J} = \sigma \vec{E}$), Energy stored in a magnetic field, Continuity equation, Displacement current and displacement current density, Basic introduction to Maxwell's equations in electromagnetism.

References:

Essential Readings:

- 1) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings
- 2) Schaum's Outlines of Electromagnetics by J. A. Edminister and M. Nahvi
- 3) Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn. 1981, McGraw-Hill.
- 4) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.
- 5) Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
- 6) Electricity and Magnetism, Tom Weideman, University of California Davis. [url: https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%209C_EM%20by%20Tom%20Weideman.pdf]

Additional Readings:

- 1) Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
- 2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
- 3) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.
- 4) Problems and Solutions in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan and Ravi Varshney.

PRACTICAL COMPONENT

Every student must perform at least five experiments.

- 1) Magnetic field variation along the axis of a circular coil and in a Helmholtz coil ($(r > a, r = a \text{ and } r < a)$). Here, 'a' is radius of coil and 'r' is distance between the coils).
- 2) **B-H** curves for soft and hard ferromagnetic materials and comparison of their coercivity, retentivity and saturation magnetization for same applied magnetic field.
- 3) Measurement of field strength **B** and its variation in a solenoid (determine $d\mathbf{B}/dx$)
- 4) Measurement of current and charge sensitivity of ballistic galvanometer
- 5) Measurement of critical damping resistance of ballistic galvanometer
- 6) Determination of a high resistance by leakage method using ballistic galvanometer
- 7) Measurement of self-inductance of a coil by Anderson's Bridge
- 8) Measurement of self-inductance of a coil by Owen's Bridge
- 9) To determine the mutual inductance of two coils by the Absolute method

References (for Laboratory Work):

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House
- 2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed., 2011, Kitab Mahal
- 3) Advanced Level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
- 4) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning
- 5) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press

**DISCIPLINE SPECIFIC CORE COURSE – 6:
 ELECTRICAL CIRCUIT ANALYSIS**

Course title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Electrical Circuit Analysis DSC – 6	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Physics and Mathematics syllabus of class XII

LEARNING OBJECTIVES

This course covers the basic circuit concepts in a systematic manner which is suitable for analysis and design. It aims at study and analysis of electric circuits using network theorems and two-port parameters.

LEARNING OUTCOMES

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

- Understand the basic concepts, basic laws and methods of analysis of DC and AC networks and their difference
- Solve complex electric circuits using network theorems.
- Discuss resonance in series and parallel circuits and also the importance of initial conditions and their evaluation.
- Evaluate the performance of two port networks.

SYLLABUS OF DSC – 6

THEORY COMPONENT

Unit 1: (4 Weeks)

Circuit Analysis: Ideal voltage source, real voltage source, current source, Kirchhoff's current law, Kirchhoff's voltage law, node analysis, mesh analysis, Star and Delta conversion
 DC Transient Analysis: Charging and discharging with initial charge in RC circuit, RL circuit with initial current, time constant, RL and RC Circuits with source

Unit 2: (6 Weeks)

AC Circuit Analysis: Sinusoidal voltage and current, Definitions of instantaneous, peak to peak, root mean square and average values, form factor and peak factor (for half-rectified and full-rectified sinusoidal wave, rectangular wave and triangular wave), voltage-current relationship in resistor, inductor and capacitor, phasor, complex impedance, power in AC

circuits, sinusoidal circuit analysis for RL, RC and RLC Circuits, resonance in series and parallel RLC Circuits (Frequency Response, Bandwidth, Quality Factor), selectivity, application of resonant circuits

Unit 3: (5 Weeks)

Network Theorems: Principal of duality, Superposition theorem, Thevenin theorem, Norton theorem, Their applications in DC and AC circuits with more than one source, Maximum Power Transfer theorem for AC circuits, Reciprocity Theorem, Millman's Theorem, Tellegen's theorem

Two Port Networks: Impedance (Z) Parameters, Admittance (Y) Parameters, Transmission Parameters, Impedance matching

References:

Essential Readings:

- 1) Electric Circuits, S. A. Nasar, Schaum's Outline Series, Tata McGraw Hill (2004)
- 2) Essentials of Circuit Analysis, Robert L. Boylestad, Pearson Education (2004)
- 3) Electrical Circuits, M. Nahvi and J. Edminister, Schaum's Outline Series, Tata McGraw-Hill (2005)
- 4) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)
- 5) Principles of Electric Circuits, Thomas L. Floyd, 9/e (2016)

Additional Readings:

- 1) Network analysis, M. E. Van Valkenburg, Third edition, Prentice Hall
- 2) Network, Lines and Fields, John D. Ryder, Pearson Ed. II, 2015.
- 3) Electrical Circuits, K. A. Smith and R. E. Alley, 2014, Cambridge University Press

PRACTICAL COMPONENT

Every student must perform at least seven experiments from the following list of experiments

- 1) Verification of Kirchoff's Law.
- 2) Verification of Superposition Theorem by using d.c. and a.c. voltage source
- 3) Verification of Norton's theorem.
- 4) Verification of Thevenin's Theorem and Maximum Power Transfer Theorem by using d.c. and a.c. voltage source
- 5) Determination of unknown capacitance using de Sauty's Bridge
- 6) Determination of time constant of RC and RL circuit
- 7) Study of frequency response of RC circuit
- 8) Study of frequency response of a parallel LCR Circuit and determination of its resonant frequency, impedance at resonance, quality factor and bandwidth.
- 9) Explore electrical properties of matter using Arduino:
 - a. To study the characteristics of a series RC Circuit.
 - b. To study the response curve of a series LCR circuit and determine its resonant frequency, impedance at resonance, quality factor and bandwidth

References (for Laboratory Work):

- 1) A Textbook of Electrical Technology, B. L. Thareja, A. K. Thareja, Volume II, S. Chand
- 2) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)
- 3) Electric Circuits, S. A. Nasar, Schaum's Outline series, Tata McGraw Hill (2004)
- 4) Electrical Circuits, K. A. Smith and R.E. Alley, 2014, Cambridge University Press
- 5) Electrical Circuit Analysis, K. Mahadevan and C. Chitran, 2nd Edition, 2018, PHI Learning Pvt. Ltd.

Category II

**Physical Science Courses for Undergraduate Programme of study with
 Physics discipline as one of the Core Disciplines
 (B. Sc. Physical Science with Physics as Major discipline)**

DISCIPLINE SPECIFIC CORE COURSE (PHYSICS DSC - 2): ELECTRICITY AND MAGNETISM

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Electricity and Magnetism Physics DSC 2	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Physics and Mathematics syllabus of class XII

LEARNING OBJECTIVES

This course reviews the concepts of electricity and magnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course covers static and dynamic electric and magnetic fields, and the principles of electromagnetic induction. It also includes analysis of electrical circuits and introduction of network theorems. The students will be able to apply the concepts learnt to several real world problems.

LEARNING OUTCOMES

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

- Understand Gauss' law, Coulomb's law for the electric field, and apply them to systems of point charges as well as line, surface, and volume distributions of charges. Also to use the knowledge to solve some simple problems
- Express electric current and capacitance in terms of electric field and electric potential.
- Calculate the force experienced by a moving charge in a magnetic field
- Determine the magnetic force generated by a current carrying conductor
- Have brief idea of magnetic materials, understand the concept of electromagnetic induction, solve problems using Faraday's and Lenz's laws

In the laboratory course, students will be able to measure resistance (high and low), voltage, current, self and mutual inductance, capacitor, strength of magnetic field and its variation, study different electric circuits.

SYLLABUS OF PHYSICS DSC – 2

THEORY COMPONENT

Unit 1: (5 Weeks)

Electrostatics: Electric field, electric flux, Gauss' theorem in electrostatics, applications of Gauss' theorem (linear, plane and spherical charge distribution), line integral of electric field, electric potential due to a point charge, electric potential and electric field of a dipole and charged disc, capacitance due to parallel plates and spherical condenser. Electrostatic energy of system of charge (charged sphere), dielectric medium, dielectric polarization, displacement vector, Gauss' theorem in dielectrics, parallel plate capacitor filled with dielectric.

Unit 2: (4 Weeks)

Magnetostatics: Magnetic force between current elements and definition of magnetic field **B**, Biot-Savart's law and its applications (current carrying straight conductor, current carrying circular coil, current carrying solenoid), divergence and curl of magnetic field, Ampere's circuital law, magnetic properties of materials (magnetic intensity, magnetic induction, permeability, magnetic susceptibility), brief introduction of dia-, para- and ferro magnetic materials

Unit 3: (3.5 Weeks)

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, self-inductance of single coil, mutual inductance of two coils, energy stored in magnetic field. Maxwell's equations and equation of continuity of current, displacement current

Unit 4: (2.5 Weeks)

DC Circuits: Review of Kirchhoff's Voltage and Current Laws, Thevenin theorem, Norton theorem, Superposition theorem, Maximum Power Transfer theorem.

References:

Essential Readings:

- 1) Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.
- 2) Electricity and Magnetism, J. H. Fewkes and J. Yarwood. Vol. I, 1991, Oxford Univ. Press
- 3) Electricity and Magnetism, D. C. Tayal, 1988, Himalaya Publishing House.
- 4) Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
- 5) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn, 1998, Benjamin Cummings.

Additional Readings:

- 1) Electricity and Magnetism, Berkeley Physics Course, Edward M. Purcell, 1986, McGraw-Hill Education.
- 2) Problems and Solutions in Electromagnetics, Ajoy Ghatak, K Thyagarajan and Ravi Varshney.

- 3) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
- 4) Schaum's Outline of Electric Circuits, J. Edminister and M. Nahvi, 3rd Edn., 1995, McGraw Hill.

PRACTICAL COMPONENT

The teacher is expected to give basic idea and working of various instruments and circuits related to different experiments. Students should also be given knowledge of recording and analyzing experimental data.

Every student should perform at least 06 experiments from the following list of experiments.

- 1) To use a multimeter for measuring resistances, a.c and d.c voltages, d.c. current, capacitance and for checking electrical fuses.
- 2) Ballistic Galvanometer:
 - a) Measurement of charge and current sensitivity
 - b) Measurement of critical damping resistance
 - c) Determine a high resistance by leakage method
 - d) Determine self-inductance of a coil by Rayleigh's Method.
- 3) To compare capacitances using de Sauty's bridge.
- 4) Measurement of field strength B and its variation in a Solenoid
- 5) To study the Characteristics of a Series RC Circuit.
- 6) To study a series LCR circuit and determine its resonant frequency and quality factor.
- 7) To study a parallel LCR circuit and determine its anti-resonant frequency and quality factor
- 8) To determine a low resistance by Carey Foster bridge.
- 9) To verify the Thevenin, superposition and maximum power transfer theorems
- 10) To verify Norton theorem

References (for Laboratory Work):

- 1) Advanced Practical Physics for Students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
- 3) A Textbook of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press
- 5) Advanced Level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

(Physical Science Courses (with Electronics) for Undergraduate Programme of study with Physics and Electronics discipline as Core Disciplines)

DISCIPLINE SPECIFIC CORE COURSE (PHYSICS DSC - 3): ELECTRICITY AND MAGNETISM

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Electricity and Magnetism Physics DSC 3	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Physics and Mathematics syllabus of class XII

LEARNING OBJECTIVES

This course reviews the concepts of electricity and magnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course covers static and dynamic electric and magnetic fields, and the principles of electromagnetic induction. It also includes analysis of electrical circuits and introduction of network theorems. The students will be able to apply the concepts learnt to several real world problems.

LEARNING OUTCOMES

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

- Understand Gauss' law, Coulomb's law for the electric field, and apply them to systems of point charges as well as line, surface, and volume distributions of charges. Also to use the knowledge to solve some simple problems
- Express electric current and capacitance in terms of electric field and electric potential.
- Calculate the force experienced by a moving charge in a magnetic field
- Determine the magnetic force generated by a current carrying conductor
- Have brief idea of magnetic materials, understand the concept of electromagnetic induction, solve problems using Faraday's and Lenz's laws

In the laboratory course, students will be able to measure resistance (high and low), voltage, current, self and mutual inductance, capacitor, strength of magnetic field and its variation, study different electric circuits.

SYLLABUS OF PHYSICS DSC – 3

THEORY COMPONENT

Unit 1: (5 Weeks)

Electrostatics: Electric field, electric flux, Gauss' theorem in electrostatics, applications of Gauss' theorem (linear, plane and spherical charge distribution), line integral of electric field, electric potential due to a point charge, electric potential and electric field of a dipole and charged disc, capacitance due to parallel plates and spherical condenser. Electrostatic energy of system of charge (charged sphere), dielectric medium, dielectric polarization, displacement vector, Gauss' theorem in dielectrics, parallel plate capacitor filled with dielectric.

Unit 2: (4 Weeks)

Magnetostatics: Magnetic force between current elements and definition of magnetic field **B**, Biot-Savart's law and its applications (current carrying straight conductor, current carrying circular coil, current carrying solenoid), divergence and curl of magnetic field, Ampere's circuital law, magnetic properties of materials (magnetic intensity, magnetic induction, permeability, magnetic susceptibility), brief introduction of dia-, para- and ferro magnetic materials

Unit 3: (3.5 Weeks)

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, self-inductance of single coil, mutual inductance of two coils, energy stored in magnetic field. Maxwell's equations and equation of continuity of current, displacement current

Unit 4: (2.5 Weeks)

DC Circuits: Review of Kirchhoff's Voltage and Current Laws, Thevenin theorem, Norton theorem, Superposition theorem, Maximum Power Transfer theorem.

References:

Essential Readings:

- 1) Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.
- 2) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press
- 3) Electricity and Magnetism, D. C. Tayal, 1988, Himalaya Publishing House.
- 4) Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
- 5) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn, 1998, Benjamin Cummings.

Additional Readings:

- 1) Electricity and Magnetism, Berkeley Physics Course, Edward M. Purcell, 1986, McGraw-Hill Education.
- 2) Problems and Solutions in Electromagnetics, Ajoy Ghatak, K Thyagarajan and Ravi Varshney

- 3) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
- 4) Schaum's Outline of Electric Circuits, J. Edminister and M. Nahvi, 3rd Edn., 1995, McGraw Hill.

PRACTICAL COMPONENT

The teacher is expected to give basic idea and working of various instruments and circuits related to different experiments. Students should also be given knowledge of recording and analyzing experimental data.

Every student should perform at least 06 experiments from the following list of experiments.

- 1) To use a multimeter for measuring resistances, a.c and d.c voltages, d.c. current, capacitance and for checking electrical fuses.
- 2) Ballistic Galvanometer:
 - e) Measurement of charge and current sensitivity
 - f) Measurement of critical damping resistance
 - g) Determine a high resistance by leakage method
 - h) Determine self-inductance of a coil by Rayleigh's Method.
- 3) To compare capacitances using de Sauty's bridge.
- 4) Measurement of field strength B and its variation in a Solenoid
- 5) To study the Characteristics of a Series RC Circuit.
- 6) To study a series LCR circuit and determine its resonant frequency and quality factor.
- 7) To study a parallel LCR circuit and determine its anti-resonant frequency and quality factor
- 8) To determine a low resistance by Carey Foster bridge.
- 9) To verify the Thevenin, superposition and maximum power transfer theorems
- 10) To verify Norton theorem

References (for Laboratory Work):

- 1) Advanced Practical Physics for Students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
- 3) A Textbook of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press
- 5) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

**DISCIPLINE SPECIFIC CORE COURSE (PHYSICS DSC - 4):
 LINEAR AND DIGITAL INTEGRATED CIRCUITS**

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Linear and Digital Integrated Circuits Physics DSC 4	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	Physics and Mathematics syllabus of class XII

LEARNING OBJECTIVES

This paper aims to provide the basic knowledge of linear and digital electronics. It discusses about the operational amplifier and its applications. Boolean algebra and combinational logic circuits are also discussed.

LEARNING OUTCOMES

At the end of this course, students will be able to achieve the following learning outcomes.

- To understand Op-Amp basics and its various applications.
- To become familiar with logic gates and boolean algebra theorems.
- To understand the minimization techniques for designing a simplified logic circuit.
- To design a half adder, full adder, half-subtractor, and full-subtractor.
- To understand the working of data processing circuits, multiplexers, de-multiplexers, decoders and encoders.
- To become familiar with the working of flip-flop circuits, its working and applications.

SYLLABUS OF PHYSICS DSC – 4

THEORY COMPONENT

Unit 1: (4 Weeks)

Operational Amplifiers (Black box approach): Characteristics of an ideal and practical Operational Amplifier (IC 741), Open and closed loop configuration, CMRR, Slew Rate and the concept of Virtual Ground.

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Summing and Difference Amplifier, (3) Differentiator, (4) Integrator, (5) Wein bridge oscillator, (6) Comparator, and (7) Active low pass and high pass Butter worth filter (1st order only).

Unit 2: (3 Weeks)

Logic Gates and Boolean algebra: Truth Tables of OR, AND, NOT, NOR, NAND, XOR, XNOR, Basic postulates and fundamental theorems of Boolean algebra.

Combinational Logic Analysis and Design: Standard representation of logic functions (SOP), Minimization Techniques (Karnaugh map minimization up to 4 variables for SOP).

Unit 3: (3 Weeks)

Arithmetic Circuits: Half and Full Adder, Half and Full Subtractor, 4-bit binary Adder/Subtractor

Data processing circuits: Multiplexers, De-multiplexers, Decoders, Encoders

Unit 4: (2.5 Weeks)

Sequential Circuits: SR, D, and JK Flip-Flops. Race-around conditions in JK Flip-Flop. Master-slave JK Flip-Flop.

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). Ring Counter.

Unit 5: (2.5 Weeks)

Counters (4 bits): Asynchronous counter, Synchronous Counter.

D-A and A-D Conversion: 4 bit binary weighted and R-2R D-A converters, A-D conversion characteristics, successive approximation ADC.

References:

Essential Readings:

- 1) Op-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- 2) Operational Amplifiers and Linear ICs, David A. Bell, 3rd Edition, 2011, Oxford University Press.
- 3) Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 8th Ed., 2018, Tata McGraw
- 4) Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill
- 5) Digital Fundamentals, Thomas L. Floyd, Pearson Education Asia (1994).
- 6) Digital Principles, R. L. Tokheim, Schaum's outline series, Tata McGraw- Hill (1994).

PRACTICAL COMPONENT

Every student should perform at least 04 experiments each from section A, B and C

Section A: Op-Amp. Circuits (Hardware design)

- 1) To design an inverting and non-inverting amplifier using Op-amp (741,351) for dc voltage of given gain.
- 2) To design inverting and non-inverting amplifier using Op-amp (741,351) and study their frequency responses
- 3) To add two dc voltages using Op-Amp in inverting and non-inverting mode.

- 4) To design a precision Differential amplifier of given I/O specification using Op-amplifier.
- 5) To investigate the use of an op-amp as an Integrator.
- 6) To investigate the use of an op-amp as a Differentiator.
- 7) To design a Wien bridge oscillator for given frequency using an Op-Amplifier.
- 8) Design a Butter-worth Low Pass active Filter (1st order) and study frequency response.
- 9) Design a Butter-worth High Pass active Filter (1st order) and study frequency response.
- 10) Design a digital to analog converter (DAC) of given specifications.

Section B: Digital circuits (Hardware design)

- 1) (a) To design a combinational logic system for a specified Truth Table.
(b) To convert Boolean expression into logic circuit & design it using logic gate ICs.
(c) To minimize a given logic circuit.
- 2) Half Adder and Full Adder.
- 3) Half Subtractor and Full Subtractor.
- 4) 4 bit binary adder and adder-subtractor using Full adder IC.
- 5) To design a seven segment decoder.
- 6) To build Flip-Flop (RS, D-type and JK) circuits using NAND gates.
- 7) To build JK Master-slave flip-flop using Flip-Flop ICs.
- 8) To build a Counter using D-type/JK Flip-Flop ICs and study timing diagram.
- 9) To make a Shift Register (serial-in and serial-out) using D-type/JK Flip-Flop ICs.

Section C: SPICE/MULTISIM simulations for electronic circuits and devices

- 1) To verify the Thevenin and Norton Theorems.
- 2) Design and analyze the series and parallel LCR circuits.
- 3) Design the inverting and non-inverting amplifier using an Op-Amp of given gain.
- 4) Design and Verification of op-amp as integrator and differentiator.
- 5) Design the 1st order active low pass and high pass filters of given cutoff frequency.
- 6) Design a Wein's Bridge oscillator of given frequency.
- 7) Design clocked SR and JK Flip-Flop's using NAND Gates.
- 8) Design 4-bit asynchronous counter using Flip-Flop ICs.

References (For Laboratory Work):

- 1) Fundamentals of Digital Circuits, Anand Kumar, 4th Edn, 2018, PHI Learning.
- 2) Digital Computer Electronics, A. P. Malvino, J.A. Brown, 3rd Edition, 2018, Tata McGraw Hill Education.
- 3) Digital Electronics, S. K. Mandal, 2010, 1st edition, Tata McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY THE DEPARTMENTS**

GENERIC ELECTIVE (GE - 11): ELECTRICITY AND MAGNETISM

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Electricity and Magnetism GE – 11	4	3	0	1	Class XII pass	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course begins with theorems of network analysis which are required to perform the associated experiments in the laboratory. Then course delves into the elementary vector analysis, an essential mathematical tool for understanding static electric field and magnetic field. By the end of the course, the student should appreciate Maxwell's equations.

LEARNING OUTCOMES

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

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

SYLLABUS OF GE – 11

THEORY COMPONENT

Unit 1: (5 Weeks)

Network Analysis: Superposition, Thevenin, Norton theorems and their applications in DC and AC circuits with more than one source, Maximum Power Transfer theorem for AC circuits

Mathematical Preliminaries: Concept of scalar and vector fields, Gradient of a scalar field, Divergence and curl of vector fields and their physical interpretation, Conservative forces and Laplace and Poisson equations.

Concept of a line integral of a scalar and vector field, surface integral of vector fields and volume integral, Gauss's theorem, Stoke's theorem.

Unit 2: (5 Weeks)

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge distributions, Electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries, Uniqueness theorem

Electric Field in Matter: Bound charges due to polarization and their physical interpretation. Average electric field inside a dielectric, Electric Field in spherical and cylindrical cavities of a dielectric, Displacement vector and its boundary conditions, Gauss' Law in the presence of dielectrics, Linear dielectrics: electric susceptibility and dielectric constant, Boundary value problems with linear dielectrics.

Unit 3: (5 Weeks)

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, integral and differential forms of Ampere's Law, Vector potential and its ambiguities.

Magnetic Properties of Matter: Magnetization vector, Bound Currents, Magnetic Intensity, Differential and integral form of Ampere's Law in the presence of magnetised materials, Magnetic susceptibility and permeability, Ferromagnetism (Hund's rule)

Electrodynamics: Faraday's Law, Lenz's Law, inductance, Electromotive force, Ohm's Law ($\vec{J} = \sigma \vec{E}$), Energy stored in a Magnetic Field. Charge Conservation, Continuity equation, Differential and integral forms of Maxwell's equations in matter.

References:

Essential Readings:

- 1) Introduction to Electrodynamics, D. J. Griffiths, 4th Edn., 2015, Pearson Education India Learning Private Limited.
- 2) Schaum's Outlines of Electromagnetics, M. Nahvi and J. A. Edminister, 2019, McGraw-Hill Education.

- 3) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.
- 4) Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
- 5) Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.
- 6) Introductory Circuit Analysis, R. Boylestead, 2016, Pearson.
- 7) Electricity and Magnetism, Tom Weideman, University of California Davis.
[url: https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%209C_EM%20by%20Tom%20Weideman.pdf]

Additional Readings:

- 1) Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
- 2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
- 3) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley

PRACTICAL COMPONENT

Learning Outcome:

- To understand working of Arduino Microcontroller System
- To use Arduino to measure time, count events and time between events
- To use Arduino to measure voltage/current/resistance
- To use Arduino to measure various physical parameters like magnetic field

Unit I (Mandatory): Arduino Programming

Introduction to Arduino Microcontroller platform. Getting acquainted with the Arduino IDE and Basic Sketch structure. Digital Input and output. Measuring time and events. Measuring analog voltage. Generating analog voltage using Pulse Width Modulation. Serial communication and serial monitor. Programming using Interrupts.

Unit II: Exploring electrical properties of matter using Arduino (at least one experiment)

- To study the characteristics of a series RC Circuit.
- To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, Impedance at resonance, (c) Quality factor Q, and (d) Band width.
- Diode Characteristics:
 - To study characteristics of diode and estimate Boltzman constant.
 - To study characteristics of LED and estimate Planck's constant

Unit III: Exploring magnetic properties of matter using Arduino

- To verify Faraday's law and Lenz's law by measuring induced voltage across a coil subjected to varying magnetic field. Also, estimate dipole moment of the magnet.

Unit IV: DC and AC Bridges (at least one experiment)

- To compare capacitances using de Sauty Bridge

- To determine a Low Resistance by Carey - Foster Bridge

Unit V: Network Theorems

(at least one experiment)

- To verify the Thevenin and Norton theorems
- To verify the Superposition, and Maximum Power Transfer Theorems

References (for Laboratory Work):

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
- 3) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed.2011, Kitab Mahal
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE - 12): THERMAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Thermal Physics GE – 12	4	3	0	1	Class XII pass	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course will review the basic concepts of thermodynamics, kinetic theory of gases with a brief introduction to statistical mechanics. The primary goal is to understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will also enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms and molecule through statistical mechanics.

LEARNING OUTCOMES

At the end of this course, students will,

- Get an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations. They are also expected to learn Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the basics of quantum statistical distributions, viz., the Bose-Einstein statistics and the Fermi-Dirac statistics.

In the laboratory course, the students are expected to measure of Planck's constant using black body radiation, determine Stefan's constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

SYLLABUS OF GE – 12

THEORY COMPONENT

Unit 1: (4 Weeks)

Laws of Thermodynamics: Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V , work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements, Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit 2: (2.67 Weeks)

Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Clausius Clapeyron Equation, Expression for $(C_P - C_V)$, C_P/C_V , TdS equations, energy equations for ideal gases.

Unit 3: (2.67 Weeks)

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (zeroth order only), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case).

Unit 4: (2.33 Weeks)

Theory of Radiation: Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

Unit 5: (3.33 Weeks)

Statistical Mechanics: Macrostate and Microstate, phase space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann law, Fermi-Dirac distribution law - Bose-Einstein distribution law - comparison of three statistics.

References:

Essential Readings:

- 1) A Treatise on Heat, Meghnad Saha, and B. N. Srivastava, 1969, Indian Press.
- 2) Heat and Thermodynamics, M. W. Zemasky and R. Dittman, 1981, McGraw Hill.
- 3) Thermodynamics, Kinetic theory and statistical thermodynamics, F. W. Sears and G. L. Salinger. 1988, Narosa.
- 4) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
- 5) Thermal Physics: S. C. Garg, R. M. Bansal and C.K. Ghosh, 2nd Ed. Tata McGraw-Hill.

Additional Readings:

- 1) Concepts in Thermal Physics: Blundell and Blundell, 2nd Ed. 2009, Oxford Univ. Press.

- 2) An Introduction to Thermal Physics: D. Schroeder 2021, Oxford Univ. Press (earlier published by Pearsons).
- 3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company.

PRACTICAL COMPONENT

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the thermal physics lab, including necessary precautions.
- 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.

Every student must perform at least four experiments from the following list.

- 1) To determine Mechanical Equivalent of Heat, J , by Callender and Barne's constant flow method.
- 2) Measurement of Planck's constant using black body radiation.
- 3) To determine Stefan's Constant.
- 4) To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
- 5) To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method by steam or electrical heating.
- 6) To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
- 7) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.

References (For Laboratory Work):

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal.
- 3) A Laboratory Manual of Physics for Undergraduate Classes, D. P. Khandelwal, 1985, Vani Publication.
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press.
- 5) An Advanced Course in Practical Physics: D. Chattopadhyay and P. C. Rakshit, New Central Book Agency

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE - 13): MODERN PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Modern Physics GE – 13	4	3	0	1	Class XII pass	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

The objective of this course is to teach the physics foundation necessary for learning various topics in modern physics which are crucial for understanding atoms, molecules, photons, nuclei and elementary particles. These concepts are also important to understand phenomena in Laser physics, condensed matter physics and astrophysics.

LEARNING OUTCOMES

After getting exposure to this course, the following topics would have learnt,

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics, laying the foundation of modern physics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion, Basic lasing action.
- The properties of nuclei like density, size, binding energy, nuclear force and structure of atomic nucleus, liquid drop model and mass formula.
- Radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
- Fission and fusion: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.

In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, and determine e/m of electron and work function of a metal. They will also find wavelength of Laser sources by single and double slit experiment, wavelength and angular spread of He-Ne Laser using plane diffraction grating.

SYLLABUS OF GE – 13

THEORY COMPONENT

Unit 1: (3.33 Weeks)

Origin of Modern Physics: Blackbody Radiation: Failure of explanation from classical theory; Planck's idea of a quantum; Quantum theory of Light: Photo-electric effect and Compton scattering, de Broglie wavelength and matter waves; Davisson-Germer experiment; Wave description of particles by wave packets, Group and Phase velocities and relation between them.

Unit 2: (3.33 Weeks)

Problems with Rutherford model: Instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen-like atoms and their spectra.

Uncertainty principle: Gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Impossibility of an electron being in the nucleus, Energy-time uncertainty principle; origin of natural width of emission lines

Unit 3: (3.33 Weeks)

Basics of quantum Mechanics: Two-slit interference experiment with photons and electrons; Concept of wave functions, linearity and superposition, Time independent Schrodinger wave equation for non-relativistic particles; Momentum and Energy operators; physical interpretation of a wave function, probabilities, normalization and probability current densities in one dimension. Problem: One dimensional infinitely rigid box. An application: Quantum dot.

Unit 4: (1.67 Weeks)

X-rays: Ionizing Power, X-ray Diffraction, Bragg's Law. Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley's Law.

LASERS: Properties and applications of Lasers. Emission (spontaneous and stimulated emissions) and absorption processes, Metastable states, components of a laser and lasing action.

Unit 5: (3.33 Weeks)

Nuclear Physics: Size and structure of atomic nucleus and its relation with atomic weight; Nature of nuclear force, Stability of the nucleus; N-Z graph, Drip line nuclei, Binding Energy, Liquid Drop model: semi-empirical mass formula.

Radioactivity: Different equilibrium, Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation:

Fission and fusion: Mass deficit and generation of energy; Fission: nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions only).

References:

Essential Readings:

- 1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
- 2) Modern Physics by R. A. Serway, C. J. Moses and C. A. Moyer, 3rd edition, Thomson Brooks Cole, 2012.
- 3) Modern Physics for Scientists and Engineers by S. T. Thornton and A Rex, 4th edition, Cengage Learning, 2013.
- 4) Concepts of Nuclear Physics by B. L. Cohen, Tata McGraw Hill Publication, 1974.
- 5) Quantum Mechanics: Theory and Applications, Ajoy Ghatak and S. Lokanathan, Laxmi Publications, 2019

Additional Readings:

- 1) Six Ideas that Shaped Physics: Particle Behave like Waves, T.A. Moore, 2003, McGraw Hill.
- 2) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
- 3) New Physics, ed. Paul Davies, Cambridge University Press (1989).
- 4) Quantum Theory, David Bohm, Dover Publications, 1979.
- 5) Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
- 6) Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
- 7) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

PRACTICAL COMPONENT

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the modern physics lab, including necessary precautions.
- 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.

Every student must perform at least 06 experiments from the following list of experiments.

- 1) Measurement of Planck's constant using black body radiation and photo-detector.
- 2) Photo-electric effect: estimate Planck's constant using graph of maximum energy of photo-electrons versus frequency of light.
- 3) To determine work function of material of filament of directly heated vacuum diode.
- 4) To determine the Planck's constant using LEDs, using at least 4 LEDs.
- 5) To determine the wavelength of H-alpha emission line of Hydrogen atom.
- 6) To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
- 7) To setup the Millikan oil drop apparatus and determine the charge of an electron.

- 8) To show the tunneling effect in tunnel diode using I-V characteristics.
- 9) To determine the wavelength of laser source using diffraction of single slit.
- 10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
- 11) To determine the wavelength of laser source using diffraction of double slits.

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, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- 3) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press.
- 5) B. Sc. Practical Physics, Geeta Sanon, R. Chand, 2016.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE - 14): INTRODUCTORY ASTRONOMY

Course Title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Introductory Astronomy GE – 14	4	3	1	0	Class XII pass	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

LEARNING OUTCOMES

After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India's contribution to astronomy, both in ancient times and in modern era.

SYLLABUS OF GE – 14

THEORY COMPONENT

Unit 1: (2.67 Weeks)

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

Unit 2: (2 Weeks)

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

Unit 3: (2.33 Weeks)

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.

Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope

Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

Unit 4: (2.67 Weeks)

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings

Exoplanets: Detection methods

Unit 5: (4 Weeks)

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter

Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type Ia), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

Unit 6: (1.33 Weeks)

Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu

Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

References:

Essential Readings:

- 1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
- 2) Fundamental of Astronomy, H. Karttunen et al. Springer
- 3) Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison-Wesley Publishing Co.
- 4) Introductory Astronomy and Astrophysics, M. Zeilik and S. A. Gregory, Saunders College Publishing.
- 5) The Molecular Universe, A. G. G. M. Tielens (Sections I, II and III), Reviews of Modern Physics, Volume 85, July-September, 2013
- 6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

Useful websites for astronomy education and citizen science research platform

- 1) <https://aladin.u-strasbg.fr/>
- 2) <http://www.astrometrica.at/>
- 3) <https://www.sdss.org/>
- 4) <http://stellarium.org/>
- 5) <https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/>
- 6) <https://setiathome.berkeley.edu/>
- 7) <https://www.radathomeindia.org/>

Additional Readings:

- 1) Explorations: Introduction to Astronomy, Thomas Arny and Stephen Schneider, McGraw Hill
- 2) Astrophysics Stars and Galaxies K. D. Abhyankar, Universities Press
- 3) Textbook of Astronomy and Astrophysics with elements of cosmology, V. B. Bhatia, Narosa Publication.
- 4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
- 5) The Physical Universe: An Introduction to Astronomy, F. H. Shu, University Science Books

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Nomenclature of certificate/diploma/degrees:

- ✓ After securing 44 credits (from semester I and II), by completing one year of study of the UG Programme with Physics as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Undergraduate Certificate in Physics**.
- ✓ After securing 88 credits (from semester I, II, III & IV), by completing two years of study of the UG Programme with Physics as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Diploma in Physics**.
- ✓ After securing 132 credits (from semester I to VI), by completing three years of study of the UG Programme with Physics as a single core discipline, if a student exits after following due procedure, he or she shall be awarded **Bachelor of Science (Honours) in Physics**.
- ✓ After securing 176 credits (from semester I to VIII), by completing four years of study of the UG Programme with Physics as a single core discipline and writes dissertation, the student shall be awarded **Bachelor of Science (Honours with Research) in Physics**.
- ✓ After securing 176 credits (from semester I to VIII), by completing four years of study of the UG Programme with Physics as a single core discipline and engages in Academic Project/Entrepreneurship, the student shall be awarded **Bachelor of Science (Honours with Academic Project/Entrepreneurship) in Physics**.