

Category II

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

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 4: WAVES AND OPTICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Waves and Optics PHYSICS DSC – 4	4	2	0	2	Class XII Pass with Science	Studied Mathematical Physics-I, Mechanics

LEARNING OBJECTIVES

This is a core course in Physics curriculum that begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

LEARNING OUTCOMES

On successfully completing the requirements of this course, the students will have the skill and knowledge to,

- Understand simple harmonic oscillation and superposition principle.
- Understand superposition of a range of collinear and mutually perpendicular simple harmonic motions and their applications.
- Understand concept of normal modes in stationary waves: their frequencies and configurations.
- Understand interference as superposition of waves from coherent sources derived from same parent source.
- Demonstrate understanding of interference experiments: Young's double slit, Fresnel's biprism, Lloyd's mirror, Newton's rings
- Demonstrate basic concepts of diffraction: Superposition of wavelets diffracted from apertures
- Understand Fraunhofer diffraction from apertures: single slit, double slit, grating
- Demonstrate fundamental understanding of Fresnel diffraction: Half period zones, diffraction of different apertures
- Laboratory course is designed to understand the principles of measurement and skills in experimental designs.

SYLLABUS OF PHYSICS DSC – 4

THEORY COMPONENT

Unit – I

(11 Hours)

Superposition of collinear harmonic oscillations: Simple harmonic motion (SHM); linearity and superposition principle; superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (beats).

Superposition of two perpendicular harmonic oscillations: Graphical and analytical methods.

Lissajous figures with equal and unequal frequencies and their uses
Superposition of two harmonic Waves: Standing (stationary) waves in a string; normal modes of stretched strings

Unit – II

(8 Hours)

Interference: Division of amplitude and division of wavefront; Young's double slit experiment: width and shape of fringes; Fresnel's biprism; Lloyd's mirror; Phase change on reflection: Stokes' treatment; Interference in thin films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau Fringes); Newton's rings: Measurement of wavelength and refractive index

Unit – III

(11 Hours)

Diffraction:

Fraunhofer diffraction: Single slit, double slit, diffraction grating

Fresnel diffraction: Fresnel's assumptions. Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light; Fresnel's diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis

References:

Essential Readings:

- 1) Vibrations and Waves, A. P. French, 1st edition, 2003, CRC press.
- 2) The Physics of Waves and Oscillations, N. K. Bajaj, 1998, Tata McGraw Hill.
- 3) Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
- 4) Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.
- 5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi
- 6) The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

Additional Readings:

- 1) Principles of Optics, M. Born and E. Wolf, 7th edition, 1999, Pergamon Press.
- 2) Optics, E. Hecht, 4th edition, 2014, Pearson Education.
- 3) Fundamentals of Optics, F. A. Jenkins and H. E. White, 1981, McGraw-Hill

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least 7 experiments to be performed from the following list

- 1) To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 -T law.
- 2) To study Lissajous figures.
- 3) Familiarization with Schuster's focusing and determination of angle of prism.
- 4) To determine refractive index of the material of a prism using sodium light.
- 5) To determine the dispersive power and Cauchy's constants of the material of a prism using mercury light.
- 6) To determine wavelength of sodium light using Fresnel biprism.
- 7) To determine wavelength of sodium light using Newton's rings.
- 8) To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped film.

- 9) To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
- 10) To determine dispersive power and resolving power of a plane diffraction grating.

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 edition, 2011, Kitab Mahal
- 3) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
- 4) A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.
- 5) B.Sc. Practical Physics, G. Sanon, 2019, R. Chand & Co

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14a: INTRODUCTION TO NUMERICAL METHODS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Introduction to Numerical Methods PHYSICS DSE 14a	4	2	0	2	Class XII Pass with Science	Elementary calculus

LEARNING OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis enabling them to solve a wide range of physics problems. The skills developed during the 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,

- Analyse a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as root finding, interpolation, least squares fitting, numerical differentiation, numerical integration, and solution of initial value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.

In the laboratory course, the students will learn to implement these numerical methods in Python and develop codes to solve various physics problems and interpret the results.

SYLLABUS OF PHYSICS DSE – 14a THEORY COMPONENT

Unit – I

(7 Hours)

Approximation and errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem; Floating point computation, overflow and underflow; IEEE single and double precision format; Rounding and truncation error, absolute and relative error, error propagation.

Solutions of algebraic and transcendental equations: Basic idea of iteration method, Bisection method, Secant method, Newton Raphson method; comparison of order of convergence.

Unit – II

(7 hours)

Interpolation: Interpolation and Lagrange polynomial, divided differences, Newton divided-difference form of the interpolating polynomial with equally spaced nodes. Theoretical error in interpolation.

Least Squares Approximation: Least squares linear regression, Least squares regression for exponential and power functions by taking logarithm.

Unit - III

(8 Hours)

Numerical Differentiation: Using finite difference to approximate derivatives of first and second order using Taylor series and error in this approximation.

Numerical Integration: Newton Cotes quadrature methods; derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial; error and degree of precision of a quadrature formula; composite formulae for trapezoidal and Simpson methods; Gauss Legendre quadrature method.

Unit - IV

(8 Hours)

Initial Value Problems: Solution of initial value problems by Euler, modified Euler and Runge Kutta (RK2, RK4) methods; local and global errors, comparison of errors in the Euler and RK methods, system of first order differential equations. Solving higher order initial value problems by converting them into a system of first order equations.

References:

Essential Readings:

- 1) Introduction to Numerical Analysis, S. S. Sastry, 5th edition, 2012, PHI Learning Pvt. Ltd.
- 2) Elementary Numerical Analysis, K. E. Atkinson, 3rd edition, 2007, Wiley India Edition.
- 3) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenger and R. K. Jain, 2012, New Age Publishers
- 4) A Friendly Introduction to Numerical Analysis, B. Bradie, 2007, Pearson India

Additional Readings:

- 1) Numerical Recipes: The art of scientific computing, W. H. Press, S. A. Teukolsky and W. Vetterling, 3rd edition, 2007, Cambridge University Press
- 2) Numerical Methods for Scientists and Engineers, R. W. Hamming, 1987, Dover Publications
- 3) Applied numerical analysis, C. F. Gerald and P. O. Wheatley, 2007, Pearson Education
- 4) Numerical Analysis, R. L. Burden and J. D. Faires, 2011, Brooks/Cole, Cengage Learning
- 5) Numerical Methods, V. N. Vedamurthy and N. Ch. S.N. Iyengar, 2011, Vikas Publishing House

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.
- The students should be encouraged to develop and present an independent project.
- **At least 12 programs must be attempted (taking two from each unit). The implementation is to be done in Python. Use of scipy inbuilt functions may be encouraged**

Unit 1

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, formatting in the print statement.

Control Structures: Conditional operations, *if*, *if-else*, *if-elif-else*, *while* and *for* Loops, indentation, break and continue, List comprehension. Simple programs for practice like solving quadratic equations, temperature conversion etc.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules. Writing functions to perform simple operations like finding largest of three numbers, listing prime numbers, etc. Use of inbuilt functions to generate pseudo random numbers.

Recommended List of Programs

- Make a function that takes a number N as input and returns the value of factorial of N . Use this function to print the number of ways a set of m red and n blue balls can be arranged.
- Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.
- Write functions to convert Cartesian coordinates of a given point to cylindrical and spherical polar coordinates or vice versa.
- Solve quadratic equations for the three cases of distinct real, double real and complex conjugate roots.

Unit 2

NumPy Fundamentals: Importing *Numpy*, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using *ones()*, *zeros()*, *random()*, *arange()*, *linspace()*. Basic array operations (*sum*, *max*, *min*, *mean*, *variance*), 2-d arrays, matrix operations, reshaping and transposing arrays, *savetxt()* and *loadtxt()*.

Plotting with Matplotlib: *matplotlib.pyplot* functions, plotting of functions given in closed form as well as in the form of discrete data and making histograms

Recommended List of Programs

- To generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.
- To plot the displacement-time and velocity-time graph for the undamped, under damped critically damped and over damped oscillator using *matplotlib* (using given formulae).
- To generate array of N random numbers drawn from a given distribution (uniform, binomial, poisson and gaussian) and draw histogram using *matplotlib* for increasing N to verify the distribution.
- 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 n th partial sum of its series for various values of n on the same graph and visualise the convergence of series.

Unit 3

Root Finding: Implement the algorithms for Bisection, Secant and Newton Raphson methods or their combinations to,

- 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) Approximate nth root of a number up to a given number of significant digits.

Unit 4

Interpolation and Least Square Fitting:

- a) Given a dataset (x, y) with equidistant x values, prepare the Newton's divided difference table. Generate a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
- b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x -values.
- c) Make Python 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 ($y = ax^b$) and
 - iii. Exponential ($y = ae^{bx}$)

The real data taken in physics lab may be used here.

- d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.

Unit 5

Differentiation and Integration:

- a) To compute the left, right and central approximations for derivative of a function given in closed form. Plot both the function and derivative on the same graph. Plot (using *matplotlib*) the error as a function of step size on a log-log graph, study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.
- b) Use integral definition of error function to compute and plot $\text{erf}(x)$ in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for small and large values of x .
- c) Verify the degree of precision of each quadrature rule.
- d) Approximate the value of π by evaluating the integral $\int_0^\infty \frac{1}{x^2+1} dx$ using Simpson and Gauss Legendre method. More integrals may be evaluated.

Unit 6

Initial Value Problems (IVP):

- a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors takes over.
- b) Radioactive decay: With a given number of initial nuclei and decay constant plot the number of nuclei left as a function of time and determine the half life
- c) Solve a system of two first order differential equations by Euler, RK2 and RK4 methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
- d) Solve a physics problem like free fall with air drag or parachute problem using RK method.
- e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

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, D. Walker, 1st edition, 2015, Scientific International Pvt. Ltd
- 4) An Introduction to Computational Physics, T. Pang, 2010, Cambridge University Press
- 5) Python Programming and Numerical Methods - A Guide for Engineers and Scientists, Q. Kong, T. Siau, A. M. Bayen, 2021, Academic Press

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14b: ANALOG ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Analog Electronics PHYSICS DSE – 14b	4	2	0	2	Class XII Pass with Science	NIL

LEARNING OBJECTIVES

This course introduces the concept of semiconductor devices and their analog applications. It also emphasizes on understanding of amplifiers, oscillators, operational amplifier and their applications.

LEARNING OUTCOMES

At the end of this course, the following concepts will be learnt.

- To learn about diodes and its uses in rectification
- To gain an insight into working principle of photodiodes, solar cells, LED and zener diode as voltage regulator
- To gain an understanding of construction and working principle of bipolar junction transistors (BJTs), characteristics of different configurations, biasing and analysis of transistor amplifier
- To be able to design and understand use of different types of oscillators
- To learn the fundamentals of operation amplifiers and understand their operations to compare, add, or subtract two or more signals and to differentiate or integrate signals etc.

In the laboratory course, the students will be able to study characteristics of various diodes and BJT. They will be able to design amplifiers, and oscillators. Also different applications using Op-Amp will be designed.

SYLLABUS OF Physics DSE – 14b

THEORY COMPONENT

Unit – I - Two-terminal devices and their applications (5 Hours)

IV characteristics of a diode and its application as rectifier (half-wave and full wave rectifier), IV characteristics of a zener diode and its use as voltage regulator, principle, structure and characteristics of (1) LED, (2) Photodiode and (3) Solar Cell

Unit – II - Bipolar junction transistors (4 Hours)

n-p-n and p-n-p transistors, IV characteristics of CB and CE configurations, active, cut-off and saturation regions, current gains α and β , relations between α and β , physical mechanism of current flow

Unit – III – Amplifiers and sinusoidal oscillators (11 Hours)

Load line analysis of transistor, DC load line and Q-point, fixed bias and voltage divider bias, transistor as 2-port network, h-parameter equivalent circuit of a transistor, analysis of a

single-stage CE amplifier using hybrid model (input and output impedance, current and voltage gain)

Sinusoidal Oscillators: General idea of positive and negative feedback, Barkhausen's criterion for self-sustained oscillations, RC phase shift oscillator, determination of frequency, Hartley and Colpitts oscillators

Unit – IV - Operational Amplifiers (Black Box approach) (10 Hours)

Characteristics of an ideal and practical Op-Amp (IC 741), open-loop and closed-loop gain, frequency response, CMRR, slew rate and concept of virtual ground

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Comparator and Zero crossing detector (7) Wein bridge oscillator

References:

Essential Readings:

- 1) Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill
- 2) Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall
- 3) Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- 4) Microelectronic circuits, A. S. Sedra, K. C. Smith and A. N. Chandorkar, 6th edition, 2014, Oxford University Press.
- 5) Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd edition, 2002, Wiley India
- 6) Electronic Principles, A. Malvino, D. J. Bates, 7th edition, 2018, Tata Mc-Graw Hill Education.
- 7) Electronic Devices and circuit Theory, R. L. Boylestad and L. D. Nashelsky, 2009, Pearson

Additional Readings:

- 1) Learning Electronic Devices and circuits, S. Salivahanan and N. S. Kumar, 3rd edition, 2012, Tata Mc-Graw Hill
- 2) Microelectronic Circuits, M. H. Rashid, 2nd edition, Cengage Learning
- 3) Microelectronic Devices and Circuits, D. A. Bell, 5th edition, 2015, Oxford University Press
- 4) Basic Electronics: Principles and Applications, C. Saha, A. Halder and D. Ganguli, 1st edition, 2018, Cambridge University Press
- 5) Solid State Electronic Devices, B. G. Streetman and S. K. Banerjee, 6th edition, 2009, PHI

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

- Session on the construction and use of specific analogue devices and experimental apparatuses used in the 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.

At least six experiments to be performed from the following list

- 1) To study the V-I characteristics of a Zener diode and its use as voltage regulator.

- 2) Study of V-I and power curves of solar cells, and find maximum power point and efficiency.
- 3) To study the characteristics of a Bipolar Junction Transistor in CE configuration.
- 4) To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
- 5) To design a Wien bridge oscillator for given frequency using an op-amp.
- 6) To design an inverting amplifier using Op-amp (741, 351) for dc voltage of given gain
- 7) To design inverting amplifier using Op-amp (741, 351) and study its frequency response
- 8) To design non-inverting amplifier using Op-amp (741, 351) and study frequency response
- 9) To add two dc voltages using Op-amp in inverting and non-inverting mode
- 10) To study the zero-crossing detector and comparator
- 11) To investigate the use of an op-amp as an integrator
- 12) To investigate the use of an op-amp as a differentiator.

References for laboratory work:

- 1) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino and M. A. Miller, 1994, Mc- Graw Hill
- 2) Student Manual for The Art of Electronics, T. C. Hayes and P. Horowitz

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14c: PHYSICS OF EARTH

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Physics of Earth PHYSICS DSE – 14c	4	3	1	0	Class XII Pass with Science	NIL

LEARNING OBJECTIVES

This course familiarizes the students with the origin of earth in the solar system and various processes occurring in atmosphere, oceans and earth's internal structure.

LEARNING OUTCOMES

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

- Have an overview of structure of the earth as well as various dynamical processes occurring on it.
- Develop an understanding of evolution of the earth.
- Apply physical principles of elasticity and elastic wave propagation to understand modern global seismology as a probe of the Earth's internal structure.
- Understand the origin of magnetic field, geodynamics of earthquakes and the description of seismic sources; a simple but fundamental theory of thermal convection; the distinctive rheological behaviour of the upper mantle and its top.
- Explore various roles played by water cycle, carbon cycle, nitrogen cycles in maintaining steady state of earth leading to better understanding of the contemporary dilemmas (climate change, bio diversity loss, population growth, etc.) disturbing the Earth
- Develop the problem solving skills by adding numerical and simulations to clarify the fundamental concepts.

SYLLABUS OF DSE – 14c

THEORY COMPONENT

Unit – I

(10 Hours)

The Earth and the Universe:

- a) General characteristics and origin of the Universe. The Big Bang Theory. Estimation of age of the Universe and Hubble constant. Formation of Galaxies. Types of galaxies, Milky Way galaxy, Nebular hypothesis, Solar system, The Terrestrial and Jovian planets (Sizes, Acceleration due to gravity, Obliquity, Flatness, Eccentricity, Density, Temperature, Pressure, Atmosphere, Moons, Exceptions in trends). Titius-Bode law. Asteroid belt. Asteroids: origin types and examples, Meteorites.
- b) Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Earth's orbit and spin, the Moon's orbit and spin.
- c) Energy and particle fluxes incident on the Earth.

Unit – II**(8 Hours)**

Structure of Earth:

- a) Internal structure of Earth: Core, mantle, magnetic field. Origin of the Magnetic field. Convection in Earth's core and production of its magnetic field. Dynamo Theory, calculation of magnetic fields, Causes of variation of Magnetic Field and Palaeomagnetism.
- b) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. Ocean circulations. Oceanic current system and effect of Coriolis forces.
- c) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

Unit – III**(8 Hours)**

Dynamical Processes:

- a) The Solid Earth: Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift.
- b) Earthquake and earthquake belts. Types and properties of Seismic waves, Richter scale, geophones.
- c) Volcanoes: types, products and distribution.
- d) Concepts of eustasy, air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

Unit – IV**(10 Hours)**

The Atmosphere

- a) The Atmosphere: Features of different layers, variation of temperature with altitude; Dry, moist and environmental lapse rate, variation of density and pressure with altitude, Types of clouds and formation.
- b) The Atmosphere: Atmospheric circulation. Causes of Atmospheric circulation, Formation of three cells, Easterlies and Westerlies, and ICTZ, Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones, tropical storms, hurricanes and tornadoes.
- c) Climate: Earth's temperature and greenhouse effect. Paleoclimate and recent climate changes. The Indian monsoon system.

Unit – V**(9 Hours)**

Disturbing the Earth – Contemporary dilemmas

- a) Hydrosphere: Fresh water depletion.
- b) Geosphere: Chemical effluents, nuclear waste.
- c) Biosphere: Biodiversity loss. Deforestation. Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.
- d) Air Pollution: Types of air pollutants, Effects on atmosphere and living organisms. Ozone Hole.

References:**Essential Readings:**

- 1) Planetary Surface Processes, H. J. Melosh, 2011, Cambridge University Press.
- 2) Holme's Principles of Physical Geology, 1992, Chapman & Hall.
- 3) Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.
- 4) Physics of the Earth, F. D. Stacey, P. M. Davis, 2008, Cambridge University Press.
- 5) Environmental Physics: Sustainable Energy and Climate Change, E. Boecker and R.V. Grondelle, 3rd edition, 2011, Wiley, UK
- 6) Atmospheric Remote Sensing (Principles and Applications, Editors – S. Tiwari and A. K.

Singh, Chapter-1 (Composition and thermal structure of the Earth's atmosphere, by S. K. Dhaka and V. Kumar), 1st edition, Elsevier

Additional Readings:

- 1) The Blue Planet: An Introduction to Earth System Science, B. J. Skinner, S. C. Portere, 1994, John Wiley & Sons.
- 2) Consider a Spherical Cow: A course in environmental problem solving, J. Harte, University Science Books.
- 3) Fundamentals of Geophysics, W. Lowrie, 1997, Cambridge University Press.
- 4) The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
- 5) Climate Change: A Very Short Introduction, M. Maslin, 3rd edition, 2014, Oxford University Press.
- 6) The Atmosphere: A Very Short Introduction, P. I. Palmer, 2017, Oxford University Press.
- 7) IGNOU Study material: PHE 15 Astronomy and Astrophysics Block