DISCIPLINE SPECIFIC CORE COURSE – DSC - 9: LIGHT AND MATTER

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Light and Matter DSC – 9	**4**	**2**	**0**	**2**	Class 12th Pass	NIL

LEARNING OBJECTIVES

The objective of this course reviews the concepts of light and matter, their properties and their dual nature. This course provides an in depth understanding of dual nature of light, interference and diffraction with emphasis on practical applications of both. It prepares the student for the modern physics and quantum mechanics courses.

LEARNING OUTCOMES

On successfully completing the requirement of this course the student will have the skill and knowledge to,

- Appreciate the dual nature of light which is part of the electromagnetic spectrum and the dual nature of matter simultaneously.
- Understand the phenomena of interference and diffraction exhibited by light and matter, their nuances and details.
- Delve in to the depth of understanding wave optics with its various kinds of interference and diffraction exhibited by light.
- Demonstrate basic concepts of diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhofer and Fresnel diffraction.
- Learn about the application of matter waves in latest technological developments of electron microscope e.g. SEM and TEM used widely for characterization in several fields of physics such as material science, nanotechnology etc.
- In the laboratory course, students will gain hands-on experience of using various optical instruments, measurement of resolving power and dispersive power, and making finer measurements of wavelength of light using Newton's rings experiment. 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 DSC - 9

THEORY COMPONENT

Unit – I - Duality of Light and matter **(5 Hours)**

Light an EM wave - Hertz's experiments; Particle characteristics by photoelectric effect and Compton effect (concepts only) and wave characteristics by interference and diffraction.

Wave properties of particles: de Broglie hypothesis, wavelength of matter waves; particle

wave complementarity: Velocity of de Broglie wave and need of a wave packet; Group and phase velocities and relation between them; equivalence of group and particle velocity, dispersion of wave groups.

Unit – II – Interference **(10 Hours)**

Division of amplitude and wave-front. Two-slit interference experiment with photons: Young's double slit experiment. 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 Fringe). Newton's Rings: Measurement of wavelength and refractive index. Single photon interference. Two-slit interference experiment with electrons.

Unit – III – Diffraction **(15 Hours)**

Fraunhofer diffraction: Single slit, double slit, diffraction grating, resolving power of grating.
Fresnel diffraction: Fresnel's assumptions, Fresnel's half-period zones for plane wave, explanation of rectilinear propagation of light, theory of a zone plate: multiple foci of a zone plate, Fresnel diffraction at straight edge, a slit and a wire by Fresnel half period zones.
Diffraction of photons (e.g. X-rays, gamma rays etc.) and particles by matter, experimental study of matter waves: Davisson-Germer experiment; Electron microscope: applications SEM, TEM.

References:

Essential Readings:

1) Concepts of Modern Physics, Arthur Beiser, McGraw-Hill, 2002
2) Modern Physics by R. A. Serway, C. J. Moses and C. A. Moyer, Thomson Brooks Cole, 2012
3) Modern Physics for Scientists and Engineers by S. T. Thornton and A. Rex, 4th Edition, Cengage Learning, 2013
4) Optics, Ajoy Ghatak, McGraw-Hill Education, New Delhi, 7th Edition
5) Fundamentals of Optics, F. A. Jenkins and H. E. White, McGraw-Hill, 1981
6) Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, R. Chand Publications, 2011
7) A Textbook of Optics N. Subrahmanyam, Brij Lal, M. N. Avadhanulu, S. Chand & Co Ltd.
8) Introduction to Optics I - Interaction of Light with Matter, Ksenia Dolgaleva, Morgan and Claypool, 2021
9) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, Cengage Learning, 2010
10) Modern Physics, G. Kaur and G. R. Pickrell, McGraw Hill, 2014
11) Schaum's Outline of Beginning Physics II: Waves, electromagnetism, Optics and Modern Physics, Alvin Halpern, Erich Erlbach, McGraw Hill.
12) Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd Edition, Tata McGraw-Hill Publishing Co. Ltd.

Additional Readings:

1) Principles of Optics, Max Born and Emil Wolf, 7th Edition, Pergamon Press, 1999
2) Introduction to Optics, Pedrotti Frank L. Cambridge University Press.
3) Optics, Eugene Hecht, 4th Edition, Pearson Education, 2014
4) Six Ideas that Shaped Physics: Particle Behave like Waves, T. A. Moore, McGraw Hill, 2003

5) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
6) Quantum Mechanics: Theory and Applications, (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, 2019
7) Optics, Karl Dieter Moller, Learning by computing with model examples, Springer, 2007
8) Modern Physics for Scientists and Engineers, J. R. Taylor, C. D. Zafiratos, M. A. Dubson, Viva Books Pvt Ltd, 2017
9) Physics of Atom, Wehr, Richards and Adair, Narosa, 2002

PRACTICAL COMPONENT

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

Mandatory activity:

- 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.
- Applications of the specific experiments done in the lab.
- Familiarization with Schuster's focusing; determination of angle of prism.

At least 6 experiments from the following list.

1) Determination of refractive index of material of prism using mercury (Hg) light.
2) To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
3) To determine wavelength of sodium light using Newton's Rings.
4) To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
5) To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
6) To determine dispersive power of a plane diffraction grating using mercury lamp.
7) To determine resolving power of a plane diffraction grating using sodium lamp.
8) To determine the wavelength of laser source using diffraction of single slit.
9) To determine the wavelength of laser source using diffraction of double slit.
10) To determine wavelength and angular spread of He-Ne laser using 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, Michael Nelson and Jon 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, Geeta Sanon, R. Chand and Co.