

WAVES AND OPTICS

(B. Sc. Semester - IV)

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By

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Preface

The revision of Physics syllabi for B.Sc.(Hons.) and B.Sc. (General) at Kurukshetra University, Kurukshetra, effective from the 2024-25 academic session under the National Education Policy, necessitated an updation and revision in Waves and Optics books. It is a great privilege for the authors to present this book for Bachelor of Physical Sciences students in their fourth semester. Though book has been written strictly in alignment with the revised syllabus, yet some relevant topics have been added for the sake of understanding and conceptual continuity of the subject. Notably, modern topics such as coherence and holography have also been explored. Some of the salient features of the book are:

1. In each chapter a number of solved numerical problems have been given.
2. Number of short questions with answers are given.
3. Selective long questions and unsolved numerical problems are provided at the end of each chapter.

With the above features, this book is intended to be self-contained and self-explanatory. Every effort has been made to ensure accuracy and clarity during the proofreading process; however, inadvertent errors or omissions may still remain. Teachers, students, and readers are kindly requested to bring such errors, omissions, or suggestions to the notice of the authors or the publisher for improvement in future editions. The authors gratefully acknowledge the contributions of national and international authors and publishers whose books, manuals, and scholarly journals available both online and offline have been consulted during the preparation of this book. All such sources have been appropriately listed in the reference section.

Dr. Navneet Kaur

Syllabus

Kurukshetra University
Bachelor of Physical Sciences
Semester – IV
Waves and Optics

Unit – I **INTERFERENCE**

Interference by Division of Wavefront: Young's double slit experiment, Coherence, Conditions of interference, Fresnel's biprism and its applications to determine the wavelength of sodium light and thickness of a mica sheet, phase change on reflection.

Interference by Division of Amplitude : Plane parallel thin film, production of colors in thin films, classification of fringes in films, Interference due to transmitted light and reflected light, wedge shaped film, Newton's rings.

Unit – II **DIFFRACTION**

Fresnel's diffraction: Huygens-Fresnel's theory, Fresnel's assumptions, rectilinear propagation of light, diffraction at a straight edge, rectangular slit and diffraction at a circular aperture. Diffraction due to a narrow slit, diffraction due to a narrow wire. Fraunhofer diffraction: Single slit diffraction, double slit diffraction, plane transmission grating spectrum, dispersive power of grating, limit of resolution, Rayleigh's criterion, resolving power of telescope and a grating.

Unit – III **POLARIZATION**

Polarization : Polarization by reflection, refraction and scattering, Malus Law, phenomenon of double refraction, Huygen's wave theory of double refraction (Normal and oblique incidence), analysis of polarized light, Nicol prism, quarter wave plate and half wave plate, production and detection of (i) plane polarized light (ii) circularly polarized light and (iii) elliptically polarized

light. Optical activity, Fresnel's theory of optical rotation, specific rotation, polarimeters (half shade and Biquartz).

Unit – IV

LASERS AND FIBRE OPTICS

Lasers: Basic concept of absorption and emission of radiations, amplification and population inversion; Main components of lasers: (i) Active Medium (ii) Pumping (iii) Optical Resonator; Properties of laser beam: Monochromaticity, Directionality, Intensity, Coherence (Spatial & Temporal coherence); Metastable state, Excitation mechanism and types of Lasers (He-Ne Laser & Ruby Laser), applications of Lasers.

Fibre Optics: Optical fibres and their properties, principal of light propagation through a optical fibre, acceptance angle and numerical aperture, types of optical fibres: single mode and multimode fibres, advantages and disadvantages of optical fibres, applications of optical fibres, fibre optic sensors: Fibre Bragg Grating.

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Chapter 1

INTERFERENCE

1.1 Introduction

The main source of natural light on Earth is the Sun. Historically, another important source of light for humans has been fire, from ancient campfires to modern kerosene lamps. With the development of electric lights and power systems, electric light has effectively replaced firelight. When an electron moves from a higher energy level to a lower one, it emits energy in the form of electromagnetic radiation, such as visible light.

The domain “optics” remains an important discipline in the world of physics. It embodies the study of light, its behaviors, and how it interacts with matter. There are many applications of optics, including telescopes, microscopes, laser technology, and medical imaging. One of the fundamental aspects of optics is the study of different types of optical devices, each with unique characteristics and functions. There are three primary types of optics. These are: Physical optics, Geometric optics, Quantum optics. Geometric optics and Physical optics are two branches of optics, which pertains to the study of light and its interactions with matter. Geometric optics deals with the behavior of light when it is treated as rays.

It focuses on the principles of reflection, refraction, and the formation of images by lenses and mirrors. Geometric optics is concerned with the paths that light rays take and how they can be manipulated using optical elements. On the other hand, physical optics, also known as wave optics, considers the wave properties of light. It explores phenomena such as interference, diffraction, and polarization, which cannot be explained by geometric optics alone. Physical optics is essential for understanding light as an

electromagnetic wave and for explaining more complex optical phenomena. The last on the list is quantum optics. This branch of optics deals with the interaction between light and matter at the quantum level. It explores the quantum nature of electromagnetic radiation and its interaction with matter, including atoms, molecules, and other quantum systems. As with the other types of optics, quantum optics is essential in many applications. One of the most significant of these is the development of quantum information technologies, such as quantum cryptography, quantum computing, and quantum teleportation. These technologies rely on the ability to manipulate and control individual quantum systems, such as single photons or atoms, to perform impossible tasks with classical systems. Another key area of research in quantum optics is the study of quantum entanglement. In this phenomenon, two or more particles become linked so that the state of one particle is correlated with the state of the other particle. This has significant implications for the development of secure communication channels and the study of fundamental physics.

Quantum optics is also used in studying systems such as quantum dots and nano crystals, which have unique optical and electronic properties that make them useful for various electronics and material science applications.

Geometrical optics explains the behavior of light based on the principle of rectilinear propagation, which states that light travels in straight lines, represented as rays. It addresses phenomena such as reflection, refraction (or transmission), dispersion, and scattering. When a light ray strikes a smooth surface, a portion of it is reflected back into the original medium—this is known as the reflection of light. Simultaneously, another portion passes into the second medium, undergoing a change in direction; this is called refraction, and the transmitted ray is referred to as the refracted ray.

Consider a ray of light travelling from air to water, according to