

PHY2712: OPTICS

Pre-requisites: PHY1010, MAT1100; **Co-requisite:** MAT2100

Background

Optics is a branch of Physics dealing with the nature and properties of light. Traditionally, Optics developed from studying the interaction of visible light with matter and the construction of instruments used to study or detect visible light. Our modern understanding of visible light is that it doubles as electromagnetic radiation and particles called photons. Other forms of electromagnetic radiation exhibits behaviors similar to visible light making them useful in many modern applications of all branches of science, technology and engineering. Optics as an area of study is broadly divided into: Geometric Optics (light as rays), Physical or Wave Optics (light as electromagnetic wave phenomena) and Quantum Optics (light as photons).

Learning Outcomes

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

- 1) State Fermat's principle and apply it in the derivation for the laws of reflection and refraction on plane surfaces.
- 2) Derive mirror formula or Gaussian formula for parabolic mirrors, and use the mirror formula locate and determine the the nature of images formed by curved mirrors.
- 3) Derive the Gaussian formula for a single spherical refracting surface, define the focal points and focal lengths (primary and secondary) associated with a refracting surface, and form images on a curved surface using the Gaussian formula for a curved refracting surface.
- 4) Derive the Gaussian formula and the Lens' maker's equation for a thin lenses and use these equations to determine the location and nature of images formed by either a single thin lenses or a combination of thin lenses in contact with each other or separated by a finite distance.
- 5) Describe the deviation of monochromatic light through a refracting prism and obtain an expression connecting for the angle of minimum deviation, refractive index of the material of the refracting prims and the prism angle.
- 6) Describe the dispersion of white light by a dispersing prism, and calculate the angular dispersion and dispersive power of a dispersing prism.

- 7) Explain the working principles of basic optical instruments (Eyeglasses, magnifying glasses, microscopes, telescopes, cameras).
- 8) Describe polarization of light, types of polarization of light and how to polarize light by the following methods – polarization by transmission (Malus' law), polarization by reflection (Brewster's angle) and polarization by scattering.

Course Content

Geometric Optics

The propagation of light

Fermat's principle, Optical path length, Reflection of Light - laws of reflection, Refraction of light - refractive index, laws of refraction, Snell's law, critical angle and total internal reflection, Refraction at curved surfaces, Light Pipes – propagation of light in fiber optics, cladding, numerical aperture, acceptance angle and acceptance cone.

Mirrors

Plane mirrors, Curved mirrors – parabolic mirrors and spherical mirrors, Types of parabolic mirrors - convex and concave mirrors, Mirror formula, Ray tracing and Image formation with parabolic mirrors, equation of parabolic mirror, Spherical mirrors and equation of spherical mirrors.

Thin lenses

Lens makers equation or thin lens formula, Types of lenses – converging and diverging lenses, Gaussian lens formula, Image formation using thin lenses, Thin-lens combinations, Plane wavefronts, Spherical wavefronts - converging and diverging wavefronts.

Thick lenses

Thick lenses – focal points and principal points, cardinal points, general thick lens formulas, effective focal length, nodal points and optical center, thin-lens combinations as a thick lens, thick lens combinations, Ray tracing using thick lenses

Aberrations in Mirrors and Lenses

Types of aberrations – Monochromatic and Chromatic aberrations

Monochromatic aberrations - spherical aberration (on a single surface and on a thin lens), coma, astigmatism, field curvature of field, distortion,

Chromatic aberrations – thin achromatic doublets, dispersive powers, Abbe numbers, separated achromatic doublets.

Optical systems

Eyeglasses – dioptic power, near sightedness and farsightedness, Magnifying glass, Eyepieces , Compound microscopes, Refracting telescopes, Reflecting telescopes - Prime focus, Newtonian, Gregorian, Cassegrain, the Camera.

Dispersion

Prisms – dispersing and reflecting prisms, Deviation of monochromatic light through a prism, Dispersion of white light using a dispersing prism, angular dispersion, dispersive power.

Physical Optics

Polarization

Types of polarization of light- linear polarization, circular polarization, elliptical polarizations, Malus' law, Polarizers – linear, circular and elliptical polarizers, wire-grid polarizers, dichroic crystals, polaroid, Polarization by transmission, Polarization by reflection - Brewster's angle, Polarization by scattering.

Interference of two beams of light

Huygen's principle, optical path difference, conditions for interference of two beams of light - constructive and destructive interference, Young's double slit experiment for interference. Interference fringes from a double source , Intensity distribution for interference from two beam of the same frequency , Interference involving multiple reflections – reflection from a plane parallel film, interference in transmitted light, fringes of equal thickness - Newton's rings

Diffraction of Light

Types of Diffraction - Fraunhofer diffraction and Fresnel Diffraction

Fraunhofer diffraction by a single slit, the double slit and diffraction by many slits, Types of apertures – rectangular and circular, Resolving power of apertures, diffraction grating and resolving power, Fresnel diffraction

Lasers

Pumping, spontaneous emission, stimulated emission

Types of Lasers

Einstein coefficients

Time Allocation:

Lectures: 3 hrs/week, Tutorials: 1hour/week, Labs:3 hours/week

Assessment:

Continuous assessment: 40%, (labs 15%, Tests 20% and Assignments 5%)

Final examination: 60%

Prescribed Textbooks:

1. A. Jenkins and H. Elliot, Fundamentals of Optics(4th edition), McGraw-Hill, 1981.
ISBN: 10:0070323305

Recommended Textbooks:

1. R. S. Longhurst, Geometrical and Physical Optics, Longman, 1986. ISBN: 13:978-0582440999
2. F. G. Smith and J. H. Thompson, Optics, John Wiley, 1988. ISBN: 13:978-0471915348
3. E. Hecht, Optics, Addison-Wesley, 1989.