BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2023-2024

COMPREHENSIVE EXAMINATION

PHY F213 **OPTICS**
Max. Marks: 75
Max. Time: 2 hrs. **PART -1 CLOSED BOOK** **Date: 09.12.23**

Instructions:
- **Write the answers in the answer book.**
- **Answer all sub-parts of a question together.**
- ***1/2 mark will be deducted for answer with wrong/missing units.***

Q.1 (a) Derive the equation of the ellipse for polarized light starting from the following components of the incident electric field: $E_y = E_{0y}cos(kz - \omega t);\ E_x = E_{ox}cos(kz - \omega t + \epsilon)$.

(b) Identify the state of polarization corresponding to the Jones matrix $\begin{pmatrix} 2 \\ 3e^{i\frac{\pi}{3}} \end{pmatrix}$ by writing it in the normalized standard form $\frac{1}{\sqrt{A^2+B^2+C^2}}\begin{pmatrix} A \\ B+iC \end{pmatrix}$. Find out the amplitudes of the *x*- and *y*-components of the electric field and the angle between them.

(c) The electric field components of a plane electromagnetic wave are
$E_x = 2E_0cos(\omega t - kz + \phi);\ E_y = E_0sin(\omega t - kz)$.
Find out the state of polarization when $\phi = \pi/2$. Draw the plot of E_x vs. E_y.

(d) Consider the superposition of an RCP wave and an LCP wave of the same amplitude and propagating in the +z direction but with slightly different phase velocities:
$E_x^r = E_0cos(k_r z - \omega t);\ E_y^r = -E_0sin(k_r z - \omega t)$
$E_x^l = E_0cos(k_l z - \omega t);\ \ E_y^l = E_0sin(k_l z - \omega t)$
where $k_r = \frac{\omega}{c}n_r$ and $k_l = \frac{\omega}{c}n_l$. *r* and *l* denote RCP and LCP waves; n_r and n_l are the corresponding refractive indices. Discuss the state of polarization of the resultant wave. The resultant state of polarized wave rotates as it propagates through the optically active medium. Write down the conditions for which an optically active substance is right-handed and left-handed. **[5 + 5 + (4 + 3) + (3 + 2)]**

Q.2

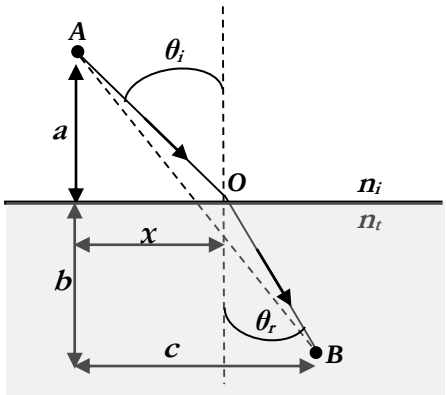


Fig. Q.2

A light ray *AO* travels from one medium to another and is refracted along *OB*. Prove Snell's law of refraction using Fermat's principle, if the total transit time from *A* to *B* is minimized. The distances and the angles are as shown in the adjacent figure. **[10]**

Q.3 In a Young's double slit experimental set-up, each slit has a width of 0.01 mm and the slit separation is 0.10 mm. The wavelength of the light used is 540 nm and the distance of the screen from the slits is 108 cm. Find **(i)** the fringe spacing and **(ii)** the distance from the central maxima to the first minimum. **[8 + 4]**

P.T.O.

Q.4 (a) The width of a rectangular slit is measured in the laboratory by means of its diffraction pattern at a distance of 2 m from the slit. When illuminated normally with a parallel beam of laser light of wavelength 632.8 nm, the distance between the third minima on either side of the principal maxima is measured to be 5.625 cm. What is the slit width?

(b) Two headlights on an automobile are 90 cm apart. How far away will the lights appear to be if they are just resolvable to a person whose pupils are just 5 mm in diameter? Assume wavelength of light to be 550 nm. **[8 + 4]**

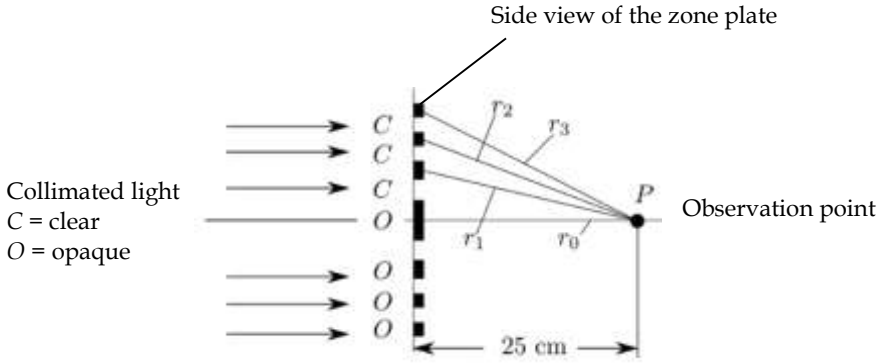
Q.5 The energy of a light beam is proportional to the square of its amplitude.

(a) Determine the percentage of light energy reflected in air from a single surface reflected in air separating a material of refractive index 1.4 for light of wavelength 500 nm.

(b) When deposited on glass of refractive index 1.6, how thick should a film of this material be in order to reduce the reflected energy by destructive interference?

(c) What is then the effective percent reflection from the film layer? **[6 + 2 + 4]**

Q.6 A zone plate has its center half-zone opaque. Find the diameters of the first two clear zones such that the plate focuses parallel light of wavelength 550 nm at 25 cm from the plate. **[7]**



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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2023-2024

COMPREHENSIVE EXAMINATION

PHY F213 **OPTICS**
Max. Marks: 60
Max. Time: 1 hr. **PART -2 OPEN BOOK** **Date: 09.12.23**

NAME:_____**ID.No.**_____**MARKS:**

Instructions:

- **Write the answers in the space provided below each question.**
- ***For answer(s) as "Linear polarization" the angle "alpha" between two components of E-field must be determined and mentioned.***
- ***1/2 mark will be deducted for answer with wrong/missing units.***

Q.1 Write down the state of polarization for each of the following Jones matrices: **[2 × 3]**

a. $\begin{pmatrix} 3i \\ i \end{pmatrix}$ **b.** $\begin{pmatrix} i \\ 1 \end{pmatrix}$ **c.** $\begin{pmatrix} 2 \\ 2i \end{pmatrix}$

Q.2. The intensities of the maxima and minima of an interference fringe pattern are in the ratio 16:9. Find out the ratio of the amplitudes. **[3]**

Q.3 The ratio of the intensities of two interfering coherent beams is α. Find out an expression for the visibility V of the fringes in terms of α. **[3]**

Q.4 The Newton's rings which are formed when the reflection of sodium light by a flat glass plate and a convex lens are viewed normally. What would be the order of the dark ring which will have double the diameter of that of the thirtieth dark ring? **[3]**

Q.5 The Fresnel biprism is used to obtain fringes from a point source that is placed 2 m from the screen and the prism is midway between the source and the screen. If the wavelength of incident light is 500 nm and the refractive index of glass is 1.5, find out the prism angle, in radians, if the separation of the fringes is 0.5 mm. **[3]**

Q.6 Find the angular resolution of the eye, in radians, which has a pupil diameter of 4 mm for a wavelength of 540 nm. **[3]**

Q.7 Two identical sheet polarizers are arranged with respect to the vertical with their transmission axis at 10° and 60°, respectively. If a linearly polarized beam with intensity Io and its electric field at 40°, enters the first polarizer, what fraction of the intensity will emerge? **[3]**

Q.8 How many lines must be ruled on a transmission grating so that it is just capable of resolving the sodium doublet 589.592 nm and 588.995 nm in the first-order spectrum? **[3]**

Q.9 Fringes are observed when a parallel beam of light of wavelength 500 nm is incident perpendicularly onto a wedge-shaped with an index of refraction of 1.5. What is the angle of the wedge, if the fringe separation is 1/3 cm? **[3]**

Q.10 A thin plate of calcite is cut with OA parallel to the plane of the plate. What minimum thickness is required to produce a quarter-wave path difference for sodium light of 589 nm? Given n_o = 1.4864 and n_e = 1.6584 of the calcite. **[3]**

Q.11 A telescope objective is 12 cm in diameter and has a focal length of 150 cm. Light of mean wavelength 550 nm from a distant star enters the scope as a nearly collimated beam. Find the radius of the central disk of light forming the image of the star on the focal plane of the objective. **[3]**

Q.12 Draw the ray velocity surfaces of a quartz crystal. Label all the relevant quantities. **[3]**

Q.13 The speed of propagation of a surface wave in a liquid of depth much greater than λ is given by $\boldsymbol{v} = \sqrt{\frac{g\lambda}{2\pi} + \frac{2\pi\gamma}{\rho\lambda}}$, where g = acceleration due to gravity, λ = wavelength, ρ = density, γ = surface tension. Find out the group velocity of a pulse, in terms of v. **[4]**

Q.14 A thin plano-convex lens is made of a material of refractive index 1.3 and the radius of the curved surface is 15 cm. Find out the longitudinal spherical aberration, for rays incident at a height of 2 cm. **[4]**

Q.15 A stream of electrons, each having an energy of 0.5 eV, impinges on a pair of extremely thin slits separated by 10^{-2} mm. What is the distance between adjacent minima on a screen 20 m behind the slits? **[3]**

Q.16 State if each of the following statements is **True** or **False** by writing ***T*** or ***F*** in the table given below. **[1×10]**

(i) One can view earth's fiery sunsets, because the blue light is appreciably attenuated; and the red, yellow lights propagate along a direction perpendicular to the line of sight along the sun.

(ii) Transverse waves on a guitar string obey the non-dispersive wave equation.

(iii) The bending of a lens found useful in reducing the spherical aberration is however not useful in reducing coma.

(iv) When the media on either side of an optical system have the same refractive index, the nodal planes coincide with the unit planes.

(v) Reflection at the polarizing angle from a dielectric surface can be used to produce circularly polarized light.

(vi) The materials that crystallize in the trigonal, tetragonal or hexagonal systems are biaxial crystals.

(vii) In Fresnel diffraction the source of light and the screen are, in general, at infinite distances from the aperture.

(viii) A full-wave plate behaves as if it were isotropic at all frequencies.

(ix) Any pulse of light can be viewed as a superposition of harmonic waves of different frequencies.

(x) For optical media, in regions of normal dispersion, the refractive index decreases with frequency and as a result group velocity is greater than phase velocity.

Q.No.	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**	**(vii)**	**(viii)**	**(ix)**	**(x)**	
Answer (T/F)											
Marks											**Tot.**

Recheck request(s), if any:

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