BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2022-2023

COMPREHENSIVE EXAMINATION

PHY F213 **Optics**

Total Marks: 135 **Date: 19.12.22**

Max.Time: 2Hrs. **PART- 1 (CLOSED BOOK)** **Max. Marks: 75**

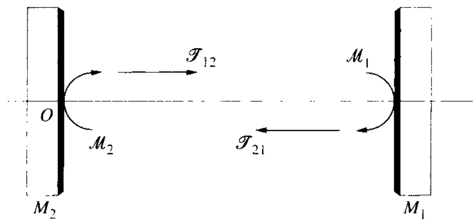
Instructions:

- ***Answer all parts of the same question together.***
- ***Answer all questions to the point.***
- ***Answers of numerical problems must be with proper units.***

Q.1 The mirror matrix M for a spherical configuration with radius R is given as: $\mathbf{M} = \begin{bmatrix} -1 & -\frac{2n}{R} \\ 0 & 1 \end{bmatrix}$.

(a) Write down M for a flat mirror in air.

(b) Figure shows two planar mirrors facing each other forming an optical cavity in air. The distance between the two mirrors is d. Light leaves point O, traverses the gap and gets reflected by mirror-1. Then, it traverses the gap again and gets reflected by mirror-2. Use matrix method to find out the system matrix **A** for this configuration in terms of d. **[2 + 10]**



Q.2 Consider a plane glass slab of thickness d made of a material of refractive index, placed in air. By simple application of Snell's law obtain an expression for the spherical aberration of the slab. Draw the ray diagram, keeping the object at the point O and labelling all relevant distances. **[10 + 2]**

Q.3 Consider a film of refractive index 1.42 in air. Assuming near normal incidence and the amplitude of incident ray as A, draw a diagram showing all reflected, refracted, transmitted rays. Label them as A_1, A_2, ..etc. Determine the amplitude of each of the rays in terms of A. **[3 + 7]**

Q.4 If the Young's double hole experiment is performed using white light, then only a few colored fringes are visible. Assuming that the visible spectrum extends from 4000Å to 7000Å, explain this phenomenon qualitatively on the basis of coherence length. **[10]**

Q.5 (A) Derive the intensity distribution of the diffraction pattern produced by N-parallel slits, each of width b, and the distance between two consecutive slits is d. The electric field due to single-slit diffraction is given as $I = I_0 \frac{sin^2\beta}{\beta}$.

(B) A plane wave of intensity I_0 is incident normally on a circular aperture as shown in the figure below. What will be the intensity on the axial point P? **[9 + 5]**

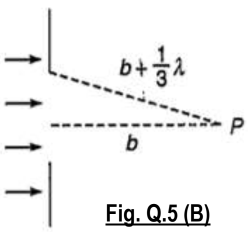


Fig. Q.5 (B)

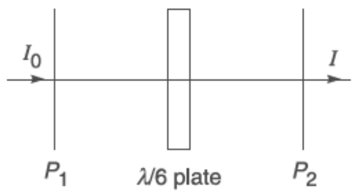


Fig. Q.6 (A)

Q.6 (A) A λ/6 plate is introduced in between the two crossed polarizers in such a way that the optic axis of the λ/6 plate makes an angle of 45° with the pass axis of the first polarizer, as shown in the figure. Consider an unpolarized beam of intensity I_0 to be incident normally on the polarizer. Assume the optic axis to be along the z-axis and the propagation along the x-axis and additionally, the plate is a negative uniaxial crystal. Write y- and z-components of the electric fields and the corresponding total intensities, after passing through **(i)** P_1 **(ii)** λ/6 plate **(iii)** P_2.

(B) Construct the Jones matrix for the half-wave plate. **[9 + 8]**

Time = 1hr. **PART-2 (Open Book)** **Max. Marks: 60**

Instructions:

- ***Write all the answers of this part in the SPACE provided below each question***
- ***Answers of numerical problems must be with proper units.***

Useful constants: $m = 9.109\times 10^{-31}$ kg; $q = 1.602\times10^{-19}$ C; $\varepsilon_0 = 8.854\times 10^{-12}$ C/Nm^2;

Atomic weight of Rb=85.48; density of Rb= 1.532 g/cm^3.

Q.1 What happens to the circular fringe pattern if a glass plate is used instead of the glass plate in a Newton's ring arrangement? Answer in one line. **[2]**

Q.2 Write down the Jones matrix for **(i)** T_{QWP}, quartz and **(ii)** linear polarizer for the y-polarized wave. **[2+2]**

Q.3 Consider a plane wave incident on a convex lens of diameter 15 cm and of focal length 30 cm. If the wavelength of light is 6500Å, calculate the radius of the first dark ring on the focal plane of the lens. **[2]**

Q.4 For a propagating wave of λ_0 = 1.5 µm, if the temporal width is 120 ps, calculate the value of γ in proper units. **[3]**

Q.5 Assuming ideal conditions, estimate the linear separation of two objects on the surface of the moon that can be just resolved by an observer on the earth using naked eye with a pupil diameter of 2 mm. Assume a wavelength of 600 nm and the distance of moon from the earth to be given by 3.84×10^5 km. **[3]**

Q.6 A soap film of refractive index μ = 1.38, under normal illumination and viewing, gives a constructive second order interference for reflected red light of λ = 690 nm. Calculate the thickness of the soap film. **[3]**

Q.7 Consider a wire grating of width 1cm having 6000 lines. Find the angular width of the second order principal maximum. Assume λ = 650 nm. **[3]**

Q.8 Assuming that the refractive index in metals is primarily due to the free electrons and that there is one free electron per atom in Rb, calculate the value of plasma wavelength λ_p (i.e. wavelength corresponding to plasma frequency) in Å for Rb. **[3]**

Q.9 In quantum mechanics, the free particle with a mass m traveling in the x-direction is given by the wave function: $\Psi(x,t) = A\exp\{i(px - Et)/\hbar\}$, where p is the momentum of the particle and $E = \frac{p^2}{2m}$, is the kinetic energy. Find out the phase velocity and the group velocity. **[3+3]**

Q.10 Parallel light of wavelength 6563Å is incident normally on a slit 0.385 mm wide. A parallel lens with a focal length of 50cm is located just behind the slit bringing the diffraction pattern to focus on a white screen. Find the distance (in mm.) from the center of principle maximum to **(i)** the first minimum and **(ii)** the fifth minimum. **[3+3]**

Q.11 The innermost zone of a zone plate has a radius of 0.425 mm. **(i)** Find the focal length of the plate (in cm.), when it is used with parallel incident light of wavelength 4471Å from a helium lamp. **(ii)** Find its first subsidiary focal length. **[3+3]**

Q.12 In the Young's double hole experiment calculate I/I_{max} where I represents the intensity at a point where the path difference is $\lambda/6$. **[3]**

Q.13 The Michelson's interferometer experiment is performed with a source that consists of two wavelengths 6554Å and 6550Å. Through what distance does the mirror have to be moved between two positions of disappearance of the fringes? **[3]**

Q.14 If the wavelength of free space is 6600Å, calculate the spectral purity for a pulse of temporal width of 5 ps. **[3]**

Q.15 State if each of the following statements is **True** or **False** by writing **T** or **F** in the table given below. **[1×10]**

(i) The chromatic aberration in an achromatic doublet is very small, if the distance between the two lenses, made of same material is equal to the mean of the focal lengths.
(ii) The shape factor q = 0.7 for the magnitude of the spherical aberration is maximum.
(iii) In calcite the o-waves travel along the fast axis whereas in quartz the e-waves travel along the slow axis.
(iv) In the system matrix for a combination of two lenses with focal lengths f_1 and f_2 separated by a distance t; all the matrix elements are related to the two focal lengths.
(v) In Young's double hole experiment, the interference fringes will be straight lines with fringe width given by $\beta = \frac{\lambda D}{d}$, where d and D have usual meanings.
(vi) As long as both incoming and outgoing waves approach being planar (differing there from a small fraction of a wavelength) over the extent of the diffracting apertures (or obstacles), Fresnel diffraction obtains.
(vii) Fraunhofer diffraction can be called as far-field diffraction.
(viii) The full-wave plate can be called as a chromatic retarder.
(ix) Calcite is used to make all kinds of retarders.
(x) Under the condition of the Brewster's angle, for the incoming unpolarized wave made up of two incoherent orthogonal P-states, only the component polarized parallel to the incident plane and therefore normal to the surface will be reflected.

Q.No.	T/F
(i)	
(ii)	
(iii)	
(iv)	
(v)	
(vi)	
(vii)	
(vii)	
(ix)	
(x)	