Register Number:
DATE: 21-11-2020

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BANGALORE-27
M.Sc. PHYSICS – III SEMESTER
SEMESTER EXAMINATION: NOVEMBER 2020
PH 9318: MODERN OPTICS

Time: 2 hours 30 min.

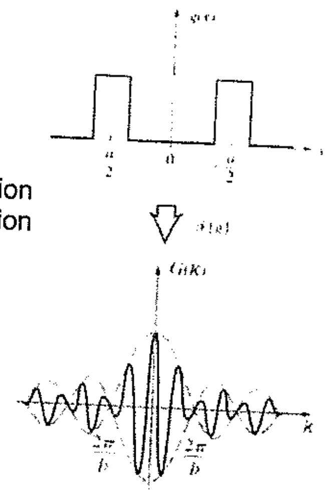
This paper contains 2 parts and 3 printed pages. **Max Marks:70**

Part-A

Answer any 5 questions. Each carries 10 marks. **(5x10=50)**

1. a) Using the following dispersion relation $n^2=1+\frac{Nq^2}{m\epsilon_o}\left(\frac{1}{\omega_o^2-\omega^2+2iK\omega}\right)$ where ω_o is the resonant frequency, ω is the frequency of the incident EM wave and K is the damping constant, explain the regions of normal and anomalous dispersion and plot n Vs ω graph representing these regions.
   b) From the above relation, obtain the relation for plasma frequency of free electrons in the ionosphere and explain for what frequency of incident electromagnetic wave can these waves be used for communication on earth through the ionosphere. (7+3)

2. The Young's double slit experiment consists of two slits each of width 'b' with separation between the slits as 'd'. The aperture function for each slit is a rectangular function given as: f(x) = 1 for $|x|\leq b/2$
   0 for $|x|>b/2$

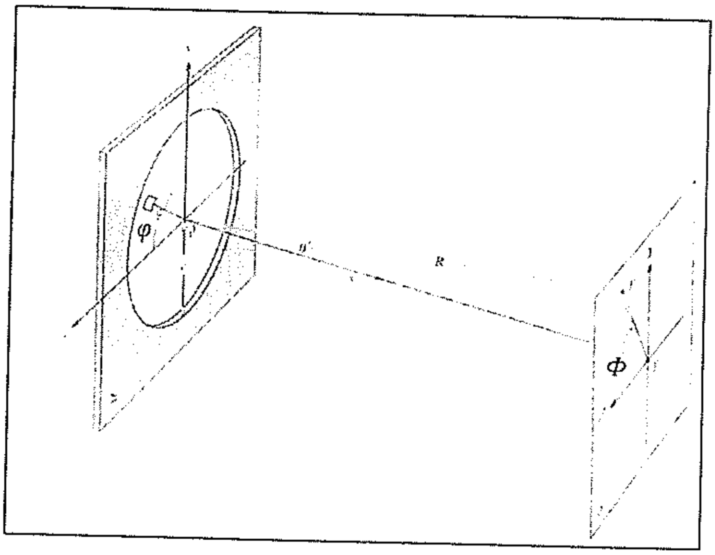
   with the two slits located at $x=\pm a/2$ represented by two symmetrical delta functions given as h(x).
   Given that the convolution of f(x) and h(x) gives the resultant aperture function g(x) and the Fourier transform of g(x) gives the resultant diffraction field G(k). With relevant figures, mathematically establish using convolution theorem that the functions f(x) and h(x) when convolved in Fourier transformed space will yield G(k).

   Given: Properties of delta function $\int_{-\infty}^{+\infty}\delta(x)f(x)dx=f(0)$ and $\int_{-\infty}^{+\infty}\delta(x-x_o)f(x)dx=f(x_o)$

3. When a monochromatic plane wave is incident on an aperture, the electric field intensity at a point P on the screen (under far-field approximation) in terms of general aperture function is given as
   $\tilde{E}(Y,Z)=\frac{\epsilon_A e^{i(\omega t-kR)}}{R}\iint_{ap} e^{ik(yY+zZ)/R}dydz$, where ϵ_A is source strength per unit area assumed to be constant over the entire aperture.
   If the field now is due to a circular aperture function (a circular opening) with radius 'a' then using spherical polar coordinates for the plane of aperture and the plane of observation find the intensity of the field at point P.

[Given :The Bessel function of (first kind) order zero is given as $J_o(u)=\frac{1}{2\pi}\int_0^{2\pi} e^{iu\cos\theta}d\theta$

and the recurrence relation for the Bessel function is $\frac{d}{du}[u^m J_m(u)]=u^m J_{m-1}(u)$].



4. a) Explain the working of an echellette grating with diagram. What is Littrow configuration?
b) Explain why the light coming from sun is partially polarized in some directions and unpolarized in some other direction. Also comment in which direction is it polarized. (6+4)

5. Michelson's interferometer is illuminated by red cadmium light source with mean wavelength of 643.85 nm which has a finite linewidth($\Delta\lambda$). Assuming the interferometer to be initially illuminated by light with two closely spaced wavelengths, derive an expression for the line width and hence spectral width of the source. Explain how will you find this spectral width experimentally. What initial adjustment do you need to do and how will you do it precisely? (knowing that actual measurement is only an approximate way of doing it.) (6+3+1)

6. What are retarders? A plane polarized wave incident normally on a negative uniaxial crystal undergoes refraction. Draw and explain which configuration of the optic axis with respect to the surface of the crystal is useful in making these retarders. Hence explain how will you make a quarter wave plate. Why is calcite not used in making these retarders?

7. Suppose we launch a wave of frequency ω from a laser source into a non-linear medium capable of showing second order non-linear effects. The incident field in real form is given as $E^{(\omega)}=E_1\cos(k_1 z-\omega t+\phi_1)$. Expressing this real field in terms of complex field (using its complex conjugate), derive the phase matching condition for the medium to propagate waves at 2ω frequency. Assume that the efficiency of conversion from ω to 2ω is low and E_1 can be assumed to be constant at such low efficiencies as the wave propagates in the medium. The general inhomogeneous wave equation for propagation of waves through such a medium is given as : $\nabla^2\vec{E}-\mu_o\epsilon\frac{\partial^2\vec{E}}{\partial t^2}=\mu_o\frac{\partial^2\vec{P}_{NL}}{\partial t^2}$
where $\vec{P}_{NL}$ is the non-linear polarisation that acts as source of electric field inside the medium.

Part-B

Answer any **4** questions. Each carries **5** marks. **(5x4=20)**

8. A crown glass double-convex lens, 4 cm thick, has an index of refraction of 1.5 with the light of wavelength 900 nm. Given that its radii of curvature of the two surfaces are 4 cm and 15 cm, find its focal length. If a television screen is placed 1.0 m (to the left) from the front face of the lens then where will the real image of the picture appear?

9. A slit of width 0.5 mm and length 3 cm is illuminated by parallel beam of light of wavelength 650 nm. If a converging lens of focal length 50 cm is placed after the slit such that the diffracted light from the slit is focussed on a screen kept in the focal plane of this lens, then what would be the location of the first minima in terms of linear displacement from the central axis.

10. Unpolarized light moving from left to right along x-axis passes through a series of four elements arranged co-axially from left to right as A,B,C,D where A is a linear polarizer alligned at an angle of 135° with the x-axis, B and C are two identical 90° retarders kept one after the other and finally the light passes through a linear polarizer again aligned at an angle of 135° with the x-axis. Analyze the light at each stage and hence comment on the light coming out of the system.

11. Find the Fourier transform of the function $f(x)=\sqrt{\frac{a}{\pi}}e^{-ax^2}$. If an airy diffraction pattern is made to pass through an apodization mask prepared using this function then how will it affect the airy diffraction pattern? Draw figure to support your answer.

12. A filter passes light with a mean wavelength of $\bar{\lambda}_o=500\,nm$. If the emerging wavetrains are roughly $20\bar{\lambda}_o$ long, then find the linewidth and frequency bandwidth of the source.

13. A collimated beam incident parallel to the symmetry axis of a certain concave mirror is reflected into a converging beam and the reflected rays converge at the focus. Use Fermat's principle to show that the mirror is paraboloid.

PH9315-A-20