Physics-1 : Tutorial Set-8 : Solutions

Solved by Tara and Priyadarshini

March 18, 2020

1. (a) Looking into a Michelson interferometer one sees a dark central disk surrounded by concentric bright and dark rings. One arm of the device is 2 cm larger than the other, and the wavelength of the light is 500 nm. Determine (i) the order of the central disc and (ii) the order of the 6th dark ring from the center.

   Ans:

   i. Here one arm of the device is $d = 2cm$ longer than the other and the operating wavelength is $\lambda = 500nm$. As the central fringe is dark, we can write
   $$2d \cos\theta = m_0\lambda$$
   where m_0 is the order of the central disc. At centre $\theta = 0$ so,
   $$m_0 = \frac{2d}{\lambda} \approx 80000$$

   ii. The order of sixth dark ring from the centre will be $(m_0 - 6) = 79994$.

   (b) In an experiment with Michelson interferometer, the distance travelled by the mirror for two successive positions of maximum distinctness is 0.2945 mm. If the mean wavelength for the two components of the source is 548.3 nm, calculate the difference between the two wavelengths.

   Ans: In this experiment, the distance traveled by the mirror is $d = 0.2945mm$ and the mean wavelength of the two source is $\lambda_{av} = 548.3nm$. We know,
   $$2d = \frac{\lambda_1\lambda_2}{\lambda_1 - \lambda_2} \approx \frac{(\lambda_{av})^2}{\lambda_1 - \lambda_2}$$
   which gives
   $$\lambda_1 - \lambda_2 \approx 0.5nm$$

2. One beam of interferometer passes through a small glass container containing a cavity 1.30 cm deep. When a gas is allowed to slowly fill the container, a total of 186 dark fringes are counted to move past a reference line. The light used has a wavelength of 610 nm. Calculate the index of refraction of the gas at its final density, assuming that the interferometere is in vacuum.

   Ans: Here $l = 1.30cm, \lambda = 610nm$ and order of fringes moved are m=186. So,

$$(n-1)l = m\lambda$$

   putting all the given values, we get the value of the refractive index of gas to be $n = 1.0088$

3. (a) A glass plate of n_g=1.5 is coated with a polymer film of n_f=2. Calculate the coating thickness so as to observe (i) maximum and (ii) minimum reflection using a light of wavelength λ=500 nm.

   Ans:

   i. The coating thickness of the film to observe maximum reflection is

$$d = \frac{\lambda}{4n_f} = 62.5nm$$

   ii. The thickness for observing minimum reflection is

$$d = \frac{\lambda}{2n_f} = 125nm$$

   (b) Diffuse Monochromatic light with λ=0.6 μm falls on a thin film of refractive index n_g=1.5. Determine the film thickness if the angular separation of neighboring maxima observed in reflected light at angles close to 45 degrees to the normal is equal to $\delta\theta = 2°$.

   Ans: For maximum intensity,

$$2n_t d \cos\theta_t = (k + \frac{1}{2})\lambda$$

   From Snell's law

$$n_i \sin\theta_i = n_t \sin\theta_t$$

   For air to film surface reflection, $n_i = 1$. Now from maximum intensity relation we have,

$$-2n_t d \sin\theta_t \delta\theta_t = \Delta k \lambda$$

   For neighbouring maxima$\Delta k = -1$. Using Snell's law we arrive at,

$$\delta\theta_t = \frac{\cos\theta_i}{\sqrt{n_t^2 - \sin^2\theta_i}} \delta\theta_i$$

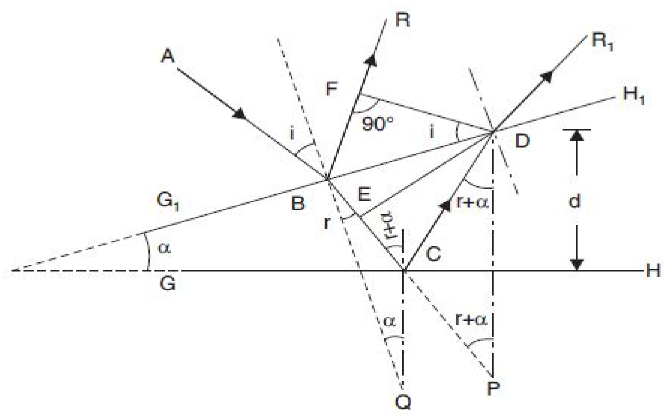
Using all of the above relation we get,

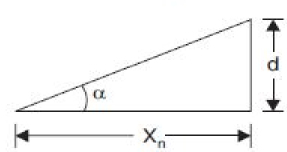
$$d = \frac{\lambda\sqrt{n_t^2 - \sin^2\theta_i}}{\sin 2\theta_i \delta\theta_i}$$

Putting all the parameters, $n_t = n_g = 1.5, \theta_i = 45°, \lambda = 0.6\mu m,\ \delta\theta_i = 2° = \pi/90 rad$ we get, $d = 22.74\mu m$

4. (a) Under the influence of gravity, a wedge-shaped film is formed when a metal is vertically dipped inside a soapy solution (μ=1.34). A coherent and monochromatic light of wavelength λ=488 nm falls near-normally on this wedge. The experimentalist observes 12 fringes per cm. Determine the wedge angle of the soap film.

Ans: For wedge shaped film thickness at n-th fringe, $d = \alpha x$, where x is the distance of the point of incidence of light from the apex. Here, $\mu = 1.34, \lambda = 488nm$. The experimentalist observes 12 fringes/cm, hence, fringe width, $\Delta x = 0.83mm$.





For normal incidence we know,

$$\Delta x = \frac{\lambda}{2\mu\alpha}$$

where α is the wedge angle of the soap film. Hence,

$$\alpha = \frac{\lambda}{2\mu\Delta x} = 0.00022rad = 0.013°$$

5. (a) A Newton's ring apparatus (comprising of a spherical surface of radius 1 m) is illuminated by light with two wavelength components. One of the wavelengths is 546 nm. If the 11th bright ring is of 546 nm fringe system coincides with the 10th ring of the other, (i) what is the second wavelength? (ii) what is the radius at which overlap takes place and the thickness of the air-film there?

Ans: The formula for a bright ring in the fringe pattern of Newton's ring arrangement is

$$r_k^2 = (k + \frac{1}{2})\frac{\lambda R}{n}$$

For air film, n = 1:

(i) Here it is given that, radius of curvature R = 1m, and λ_1=546 nm. If 11 th bright ring (k =10) of λ_1 coincide with the 10 th ring (k = 9) of λ_2, then

$$21\lambda_1 = 19\lambda_2$$

Hence, λ_2=603.5 nm

(ii) Therefore the radius at which overlap takes place is

$$r = 2.4mm$$

Thickness of air film at that point will be

$$t = \frac{r^2}{2R} = 2.87\mu m$$

(b) When a Newton's ring apparatus is immersed in a liquid, the diameter of the eigth dark ring decreases from 2.92 cm to 2.60 cm. What is refractive index of the liquid?

Ans: The diameter of the eighth dark ring decreases from 2.92 cm to 2.60 cm. Since we know the diameter of the m th dark ring is

$$(D_m)^2 = 4m\lambda R \tag{1}$$

where film is air, if the intermediate medium is liquid of refractive index of n, then diameter of the m-th dark ring will be

$$(D_m)^2 = \frac{4m\lambda R}{n} \tag{2}$$

From the above two equations we get the refractive index of liquid is n = 1.26.