SHORT QUESTIONS

9.1 Under what conditions two or more sources of light behave as coherent sources?

Ans. Two or more sources of light behaves as coherent sources if they have no phase difference or have a constant phase difference between the waves emitted by them.

A common method for producing two coherent light sources is to use single source to illuminate a screen containing two narrow slits. Hence two or more sources derived from a single source of light behaves as coherent source because they are in the same phase.

9.2 How is the distance between interference fringes affected by the separation between the slits of Young's experiment? Can fringes disappear?

Ans. The fringe spacing or distance between two consecutive bright or dark fringes in young's experiment is given by

$$\Delta y = \frac{\lambda L}{d}$$

where λ is the wavelength of light used, L is the distance of screen and source and d is the separation of slits. This relation shows that the fringe spacing is inversely proportional to the separation of slits. It means that greater the separation between the slits, the smaller will be fringe spacing. If by increasing the separation, the fringe spacing decreases and the bright fringes becomes so close that uniform intensity of light is seen and fringes disappear.

9.3 Can visible light produce interference fringes? Explain.

Ans. Yes, the white light or visible light can produce the interference fringes. Since the white light is the mixture of seven colours so each colour will produce interference fringes corresponding to its own wavelength. Hence the fringe pattern will be coloured but the fringes will be so closed that it would be difficult to observe the interference fringes of visible or white light.

9.4 In the Young's experiment, one of the slits is covered with blue filter and other with red filter. What would be the pattern of light intensity on the screen?

Ans. Since red and blue light have different wavelengths and will not be in phase coherence. Therefore there will be no dark and bright bands on the screen. So the interference of light cannot be observed properly. For better interference pattern, the monochromatic light should be used.

9.5 Explain whether the Young's experiment is an experiment for studying interference or diffraction effects of light.

Ans. Young's double slit experiment is basically used to study the interference of light. However spreading of light around the corners of the slits also produce diffraction of light. However interference on the screen takes place only when the light coming out of the narrow slits suffers from diffraction first.

9.6 An oil film spreading over a wet footpath shows colours. Explain how does it happen?

Ans. The colours are seen on the oil film spreading on the wet foot path due to interference of light waves. When a light beam is incident, a part of it is reflected from the upper surface of the then oil film and a part of it is reflected from the lower surface of the thin film. The two reflected beams are coherent. When oil film is very thin, these coherent beams overlap. Hence constructive and destructive interference exhibit colours.

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9.7 Could you obtain Newton's rings with transmitted light? If yes, would the pattern be different from that obtained with reflected light?

Ans. Yes, Newton rings can be obtained with transmitted light. However no phase is changed in transmitted light, so bright fringes can be replaced by dark fringes and so on. In case of transmitted light, the central point is bright.

9.8 In the white light spectrum obtained with a diffraction grating, the third order image of a wavelength coincides with the fourth order image of a second wavelength. Calculate the ratio of the two wavelengths.

Ans. For diffraction grating, the equation is

$$d \sin\theta = n\lambda$$

where d sin θ is the phase difference, and n is the number of order and λ is the wavelength of light used.

For first wavelength λ_1 and 3rd order, $n = 3$

$$d \sin\theta = 3\lambda_1 \qquad \ldots\ldots \text{(i)}$$

and for second wavelength λ_2 and fourth order, $n = 4$

$$d \sin\theta = 4\lambda_2 \qquad \ldots\ldots \text{(i)}$$

Equating the eq. (i) and (ii)

$$3\lambda_1 = 4\lambda_2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{4}{3}$$

$$\lambda_1 : \lambda_2 = 4 : 3$$

9.9 How would you manage to get more orders of spectra using a diffraction grating?

Ans. For diffraction grating, the equation is given by

$$d \sin\theta = n\lambda$$

where d is the grating element, λ is the wavelength. In order to get more orders of spectra from $\theta = 0°$ to $\theta = 90°$ for a given wavelength, the grating element d must be increased i.e. Less number of lines per unit length be ruled on diffraction grating.

9.10 Why the polaroid sunglasses are better than ordinary sunglasses?

Ans. The sunlight reflected from smooth surfaces such as water, wet roads, lakes and glass is horizontally polarized and produces glare. This glare can be reduced by using polariod sunglasses because they can decrease the intensity of light passing through them. Hence the polariod sunglasses are better than ordinary sunglasses. Since polariod sunglass reduce the glare of light entering into the eye.

9.11 How would you distinguish between un-polarized and plane-polarized lights?

Ans. Un-polarized and plane polarized light can be distinguished from each other by using polarizer. When light is viewed through polarizer and it can be seen continuously even if the polarizer is rotated, the light seen is unpolarized. However if on rotating the polarizer, the light becomes dim and cuts off by rotating the polarizer through 90°, then the light observed is plane polarized light.

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9.12 Fill in the Blanks:

(i) According to ———— principle, each point on a wavefront acts as a source of secondary ————.

(ii) In Young's experiment, the distance between two adjacent bright fringes for violet light is ———— than that for green light.

(iii) The distance between bright fringes in the interference pattern ———— as the wavelength of light used increase.

(iv) A diffraction grating is used to make a diffraction pattern for yellow light and then for red light. The distances between the red spots will be ———— than that for yellow light.

(v) The phenomenon of polarization of light reveals that light waves are ———— waves.

(vi) A polaroid is a commercial ————.

(vii) A polaroid glass ———— glare of light produced at a road surface.

Ans. (i) Huygen's, wavelets (ii) less (iii) increases (iv) more

(v) transverse (vi) polarizer (vii) eliminates (reduces)

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PROBLEMS WITH SOLUTIONS

PROBLEM 9.1

Light of wavelength 546 nm is allowed to illuminate the slits of Young's experiment. The separation between the slits is 0.10 mm and the distance of the screen from the slits where interference effects are observed is 20 cm. At what angle the first minimum will fall? What will be the linear distance on the screen between adjacent maxima?

Data

Wavelength of light $= \lambda = 546$ nm

$= 546 \times 10^{-9}$ m

Separation between the slits $= d = 0.10$ mm

$= 0.10 \times 10^{-3}$ m

Distance of screen from the slit $= L = 20$ cm

$= 20 \times 10^{-2}$ m

To Find

Angle for minimum fall $= \theta = ?$

Fringe spacing $= \Delta y = ?$

SOLUTION

Angle for minimum fall is

$$d \sin\theta = \left(m + \frac{1}{2}\right)\lambda$$

$$\sin\theta = \frac{\left(m + \frac{1}{2}\right)\lambda}{d}$$

For 1st minimum m = 0

$$\sin\theta = \frac{\lambda}{2d}$$

$$\sin\theta = \frac{546 \times 10^{-9}}{2 \times 0.10 \times 10^{-3}}$$

$$\sin\theta = 2730 \times 10^{-9+3}$$

$$\sin\theta = 2730 \times 10^{-6}$$

$$\theta = \sin^{-1}(0.002730)$$

$$\theta = 0.156$$

$$= 0.16^\circ$$

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For Fringe spacing

$$\boxed{\Delta y = \frac{L\lambda}{d}}$$

$$\Delta y = \frac{20 \times 10^{-2} \times 546 \times 10^{-9}}{0.10 \times 10^{-3}}$$

$$= 109200 \times 10^{-2-9+3}$$

$$= 109200 \times 10^{-8}$$

$$= 1.09 \times 10^{-3}\ \text{m}$$

$$\Delta y = 1.09\ \text{mm}$$

Result

Angle for minimum fall = θ = 0.16°

Fringe spacing = Δy = 1.09 mm

PROBLEM 9.2

Calculate the wavelength of light, which illuminates two slits 0.5 mm apart and produces interference pattern on a screen placed 200 cm away from the slits. The first bright fringe is observed at a distance of 2.40 mm from the central bright image.

Data

Distance between slits = d = 0.5 mm

= 0.5×10^{-3} m

Distance of screen from slits = L = 200 cm

= 2 m

For 1st bright fringe = m = 1

Distance of 1st bright fringe = y = 2.40 mm

= 2.40×10^{-3} m

To Find

Wavelength of light = λ = ?

SOLUTION

By formula

$$y = \frac{m\lambda L}{d}$$

$$\boxed{\lambda = \frac{y \times d}{mL}}$$

Putting the value, for 1st bright m = 1

$$\lambda = \frac{2.40 \times 10^{-3} \times 0.5 \times 10^{-3}}{1 \times 2}$$

$$= 0.6 \times 10^{-6}$$

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$$= 6 \times 10^{-7}\ \text{m}$$

$$= 600 \times 10^{-9}\ \text{m}$$

$$\lambda = 600\ \text{nm}$$

Result

Wavelength of light = λ = 600 nm

or = 6×10^{-7} m

PROBLEM 9.3

In a double slit experiment the second order maximum occurs at θ = 0.25°. The wavelength is 650nm. Determine the slit separation.

Data

Second order maxima = m = 2

Angle = θ = 0.25°

Wavelength of light = λ = 650 nm

= 650×10^{-9} m

To Find

Slit separation = d = ?

SOLUTION

By formula

$$d \sin\theta = m\lambda$$

$$\boxed{d = \frac{m\lambda}{\sin\theta}}$$

$$d = \frac{2 \times 650 \times 10^{-9}}{\sin 0.25°}$$

$$= \frac{1300 \times 10^{-9}}{4.36 \times 10^{-3}}$$

$$= \frac{1300 \times 10^{-9}}{0.00430}$$

$$= 298165.1 \times 10^{-9}$$

$$= 0.298 \times 10^{-3}$$

$$= 0.30 \times 10^{-3}\ \text{m}$$

$$d = 0.30\ \text{mm}$$

Result

Slit separation = d = 0.30 mm

PROBLEM 9.4

A monochromatic light of λ = 588 nm is allowed to fall on the half silvered glass plate G_1, in the Michelson interferometer. If mirror M_1 is moved through 0.233 mm, how many fringes will be observed to shift?

Data

Wavelength of light $= \lambda = 588 \text{ nm}$

$= 588 \times 10^{-9} \text{ m}$

Distance moved by mirror M_1 $= L = 0.233 \text{ mm}$

$= 0.233 \times 10^{-3} \text{ m}$

To Find

Number of fringes $= m = ?$

SOLUTION

By formula

$$L = m\frac{\lambda}{2}$$

$$\boxed{m = \frac{2L}{\lambda}}$$

$$m = \frac{2 \times 0.233 \times 10^{-3}}{588 \times 10^{-9}}$$

$$= \frac{0.466 \times 10^{-3}}{588 \times 10^{-9}}$$

$$= 7.92 \times 10^{-3-4+9}$$

$$= 7.92 \times 10^{2}$$

$$m = 792$$

Result

Number of fringes $= m = 792$

PROBLEM 9.5

A second order spectrum is formed at an angle of 38.0° when light falls normally on a diffraction grating having 5400 lines per centimetre. Determine wavelength of the light used.

Data

For second order spectrum $= n = 2$

Angle of diffraction $= \theta = 38.0^\circ$

Number of lines on grating $= N = 5400 \text{ lines/cm}$

$= 540000 \text{ lines/m}$

To Find

Wavelength of light $= \lambda = ?$

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SOLUTION

By formula

$$d\sin\theta = n\lambda$$

$$\boxed{\lambda = \frac{d\sin\theta}{n}} \qquad \text{But} \qquad d = \frac{1}{N} = \frac{1}{540000}$$

$$\lambda = \frac{\frac{1}{540000}\times\sin 38.0}{2}$$

$$= \frac{0.615}{540000\times 2}$$

$$= \frac{0.615}{1080000}$$

$$= 5.69\times 10^{-7}$$

$$= 5.70\times 10^{-7}\ \text{m}$$

$$= 570\times 10^{-9}\ \text{m}$$

$$\lambda = 570\ \text{nm}$$

Result

Wavelength of light = λ = 570 nm

PROBLEM 9.6

A light is incident normally on a grating which has 2500 lines per centimetre. Compute the wavelength of a spectral line for which the deviation in second order is 15.0°.

Data

Number of lines on grating = N = 2500 /cm

= 2500×100 /m

= 250000 /m

Angle of diffraction = θ = 15°

For second order = n = 2

To Find

Wavelength of light = λ = ?

SOLUTION

By formula

$$d\sin\theta = n\lambda$$

$$\lambda = \frac{d\sin\theta}{n}$$

As

$$d = \frac{1}{N}$$

$$= \frac{1}{250000}$$

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$$\text{So} \qquad \lambda = \frac{\frac{1}{250000} \times \sin 15^\circ}{2}$$

$$= \frac{0.2588}{500000}$$

$$= 5.176 \times 10^{-7}$$

$$= 517.6 \times 10^{-9}\ \text{m}$$

$$\lambda = 518\ \text{nm}$$

Result

Wavelength of light = λ = 518 nm

PROBLEM 9.7

Sodium light (= 589 nm) is incident normally on a grating having 3000 lines per centimetre. What is the highest order of the spectrum obtained with this grating?

Data

Wavelength of sodium light = λ = 589 nm

= 589×10^{-9} m

Number of lines on grating = N = 3000 /cm

= 300000 /m

Angle of grating (for highest order) = θ = 90°

To Find

Highest order of spectrum = n = ?

SOLUTION

By formula

$$d \sin\theta = n\lambda$$

$$\boxed{n = \frac{d \sin\theta}{\lambda}} \qquad \text{But} \qquad d = \frac{1}{N} = \frac{1}{300000}$$

$$\text{So} \qquad n = \frac{\frac{1}{300000} \times \sin 90^\circ}{589 \times 10^{-9}}$$

$$= 5.66 \times 10^{-9} \times 10^{9}$$

$$n = 5.66$$

Result

Highest order of spectrum = n = 5^{th}

PROBLEM 9.8

Blue light of wavelength 480 nm illuminates a diffraction grating. The second order image is formed at an angle of 30° from the central image. How many lines in a centimeter of the grating have been ruled?

Data

Wavelength of light $= \lambda = 480$ nm

$= 480 \times 10^{-9}$ m

Angle $= \theta = 30°$

For second order image $= n = 2$

To Find

Number of lines per centimeter $= N = ?$

SOLUTION

By using the formula

$$d \sin\theta = n\lambda$$

$$\boxed{d = \frac{n\lambda}{\sin\theta}}$$

$$= \frac{2 \times 480 \times 10^{-9}}{\sin 30°}$$

$$= \frac{960 \times 10^{-9}}{0.5}$$

$$d = 1920 \times 10^{-9}$$

But $$N = \frac{1}{d}$$

$$= \frac{1}{1920 \times 10^{-9}}$$

$$= 5.20 \times 10^{-4+9}$$

$$= 5.20 \times 10^{5} \text{ /m}$$

$$N = 5.20 \times 10^{3} \text{ /cm}$$

Result

Number of lines per centimeter $= N = 5.2 \times 10^{3}$

PROBLEM 9.9

X-rays of wavelength 0.150 nm are observed to undergo a first order reflection at a Bragg angle of 13.3° from a quartz (SiO_2) crystal. What is the interplaner spacing of the reflecting planes in the crystal?

Data

Wavelength of light $= \lambda = 0.150$ nm

$= 0.150 \times 10^{-9}$ m

For 1st order reflection = n = 1

Bragg's angle = θ = 13.3°

To Find

Interplaner spacing = d = ?

SOLUTION

According to Bragg's law

$$2d \sin\theta = n\lambda$$

$$\boxed{d = \frac{n\lambda}{2\sin\theta}}$$

Putting the values

$$\begin{aligned} d &= \frac{1 \times 0.150 \times 10^{-9}}{2 \sin 13.3^\circ} \\ &= \frac{0.150 \times 10^{-9}}{0.230 \times 2} \\ &= \frac{0.150 \times 10^{-9}}{0.460} \\ &= 0.326 \times 10^{-9} \text{ m} \\ d &= 0.326 \text{ nm} \end{aligned}$$

Result

Interplaner spacing of the reflecting planes in the crystal = d = 0.326 nm

or d = 0.326×10^{-9} m

PROBLEM 9.10

An X-ray beam of wavelength λ undergoes a first order reflection from a crystal when its angle of incidence to a crystal face is 26.5°, and an X-ray beam of wavelength 0.097 nm undergoes a third order reflection when its angle of incidence to that face is 60.0°. Assuming that the two beams reflect from the same family of planes, calculate (a) the interplanar spacing of the planes and (b) the wavelength λ.

Data

For 1st wavelength λ_1

Angle of incidence = θ_1 = 26.5°

First order reflection = n_1 = 1

For second wavelength λ_2

Angle of incidence = θ_2 = 60°

Third order reflection = n_2 = 3

Wavelength of second beam = λ_2 = 0.097 nm

= 0.097×10^{-9} m

To Find

(a) Interplaner spacing of the planes = d = ?

(b) Wavelength of 1st beam = λ_1 = ?

SOLUTION

(a) For interplaner spacing, by using Bragg's law

$$2d \sin\theta = n\lambda$$

For 1st beam

$$2d \sin\theta_1 = n_1\lambda_1$$

$$\boxed{\lambda_1 = \frac{2d \sin\theta_1}{n_1}}$$

Putting the values

$$\lambda_1 = \frac{2 \times d \sin 26.5^\circ}{1}$$

$$\lambda_1 = 0.892\, d \qquad \ldots\ldots \text{(i)}$$

For 2nd beam

$$\lambda_2 = \frac{2d \sin\theta_2}{n_2}$$

$$\boxed{d = \frac{\lambda_2 n_2}{2 \sin\theta_2}}$$

$$d = \frac{0.097 \times 10^{-9} \times 3}{2 \sin 60^\circ}$$

$$= \frac{0.291 \times 10^{-9}}{2 \times 0.866}$$

$$= 0.168 \times 10^{-9}\ \text{m}$$

$$d = 0.168\ \text{nm}$$

For 1st wavelength, putting in eq. (i)

$$\lambda_1 = 0.892 \times d$$

$$= 0.892 \times 0.168$$

$$\lambda_1 = 0.150\ \text{nm}$$

Result

(a) Interplaner spacing = d = 0.168 nm

(b) Wavelength of 1st beam = λ_1 = 0.150 nm

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