

Numericals

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Q.1 How many fringes will pass a reference point if the mirror of a Michelson's interferometer is moved by 0.08mm? The wavelength of light used is 5800Å°. (1998)

Given Data:

$$\begin{aligned}\text{Displacement of mirror} &= x = 0.08\text{mm} = 0.08 \times 10^{-3}\text{m} \\ \text{Wave length of light} &= \lambda = 5800\text{Å}^\circ = 5800 \times 10^{-10}\text{m}\end{aligned}$$

To Find:

$$\text{No. of fringes} = m = ?$$

Solution:

We know in Michelson's interferometer

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

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

$$m = \frac{2 \times 0.08 \times 10^{-3}}{5800 \times 10^{-10}}$$

$$m = \frac{2 \times 8 \times 10^{-5}}{58 \times 10^{-8}}$$

$$m = \frac{16}{58} \times 10^3$$

$$m = 0.275.86 \times 10^3$$

$$m = 275.86$$

$$m = 275 \text{ Fringes}$$

Ans.

Self test: (1)

- (i) 271 fringes pass a reference point when the moveable mirror of the Michelson's interferometer is moved by 0.08mm. Find the wavelength of the light used in angstrom. Ans. [(5900Å°)] (2002 P.E)

Self test: (2)

- (ii) How much should the moveable mirror of the Michelson's interferometer be moved in order to observe 400 fringes with reference to point the wavelength of the light used is 5890Å°? Ans. [0.001] (2002 P.E)

Self test: (3)

How many fringes will pass a reference point if the mirror of a Michelson's interferometer is moved by 0.08mm if the wave length of light used is 5500Å°? Ans. [291 fringes] (2007 Supp.)

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Q.2 In a double slit experiment, the separation of the slits is 1.9mm and the fringe spacing is 0.31mm at a distance of 1 metre from the slits. Find the wavelength of light? (2006 Supp.)

Given Data:

$$\begin{aligned} \text{Separation of slits} &= d = 1.9\text{mm} = 1.9 \times 10^{-3}\text{m} \\ \text{Fringe spacing} &= \Delta Y = 0.31\text{mm} = 0.31 \times 10^{-3}\text{m} \\ \text{Distance from slits} &= L = 1\text{m} \end{aligned}$$

To Find:

$$\text{Wavelength of light} = \lambda = ?$$

Solution:

$$\text{Fringe Spacing} \\ \Delta Y = \frac{L\lambda}{d}$$

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

$$\lambda = \frac{0.31 \times 10^{-3} \times 1.9 \times 10^{-3}}{1}$$

$$\lambda = 0.31 \times 1.9 \times 10^{-6}$$

$$\lambda = 5.89 \times 10^{-7}\text{m} \quad \text{Ans.}$$

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Self test: (4)

In a double slit experiment, the separation of the slits is 1.8mm and the fringe spacing is 0.31mm at a distance of 1200mm from the slits. Find the wave length of light. (2002 P.E)

$$\text{Ans. } [4.65 \times 10^{-7}\text{m}]$$

Q.3 Interference fringes were produced by two slits 0.25mm apart on a screen 150mm from the slits. If eight fringes occupy 2.62mm. What is the wavelength of the light producing the fringes?

Given Data:

$$\begin{aligned} \text{Separation of slits} &= d = 0.25\text{mm} = 0.25 \times 10^{-3}\text{m} \\ \text{Distance from the slits} &= L = 150\text{mm} = 150 \times 10^{-3}\text{m} \\ 8 \text{ fringes occupies} &= 2.62\text{mm} = 2.62 \times 10^{-3}\text{m} \end{aligned}$$

To Find:

$$\text{Wavelength} = \lambda = ?$$

Solution:

$$8 \text{ fringes occupy} = 2.62 \times 10^{-3}\text{m}$$

$$1 \text{ fringe occupy} = \frac{2.62 \times 10^{-3}}{8}$$

$$\Delta Y = 0.3275 \times 10^{-3}\text{m}$$

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Fringe Spacing

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

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

$$\lambda = \frac{0.3275 \times 10^{-3} \times 0.25 \times 10^{-3}}{150 \times 10^{-3}}$$

$$\lambda = 0.0005458 \times 10^{-6} \times 10^3$$

$$\lambda = 5458 \times 10^{-10} \text{m}$$

$$\lambda = 5458 \text{\AA} \quad \text{Ans.}$$

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Self test: (5)

In a young's double slit experiment the slits are at a distance of 1.8mm and five fringes occupy 15mm at a distance of 120cm from the slits. Find the wavelength of light? *Ans: [4.5 x 10⁻⁶m]* (2005 Supp.)

Self test: (6)

Interference fringes were produced by light coming from two slits 0.3mm apart. If five fringes occupied 1.75mm on a screen at 2000mm from the slits find the wave length of light used. *Ans: [5.25 x 10⁻⁸m]* (2000)

Self test: (7)

Interference fringes were produced by two sites 0.25mm apart on a screen 150mm from the slits. If ten fringes occupy 3.275mm. What is the wave length of the light producing fringes. *Ans: [5.45 x 10⁻⁷m]* (2008)

Q.4 Green light of a wavelength 5400A° is diffracted by grating having 2000 lines/cm. (2010, 2014)

(a) Compute the angular deviation of the third order image.

(b) is a 10th order image possible?

(1998, 2005, 2007 Failures)

Given Data:

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Wavelength of light = $\lambda = 5400 \text{\AA} = 5400 \times 10^{-10} \text{m}$

Length of grating = $L = 1 \text{cm} = 1 \times 10^{-2} \text{m}$

No. of lines = 2000 lines

(a) No. of order = $m = 3$

(b) No. of order = $m = 10$

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To Find:

Angular deviation = $\theta = ?$

Solution:

Grating element = $d = \frac{\text{Length of grating}}{\text{No. of lines}}$

$d = \frac{1 \times 10^{-2}}{2000}$

$d = 5 \times 10^{-6} \text{m}$

(a) We know in diffraction grating equation

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

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

$$\sin \theta = \frac{3 \times 5400 \times 10^{-10}}{5 \times 10^{-6}}$$

$$\sin \theta = \frac{1.62 \times 10^{-6}}{5 \times 10^{-6}}$$

$$\sin \theta = 0.324$$

$$\theta = \sin^{-1}(0.324)$$

$$\theta = 18.9^\circ \quad \text{Ans.}$$

(b) $\sin \theta = \frac{10 \times 5400 \times 10^{-10}}{5 \times 10^{-6}}$

$$\sin \theta = 1.08$$

Since value of $\sin \theta$ cannot be greater than 1, therefore 10th order image is impossible.

Self test: (8)

A diffraction grating having 200 lines per millimeter is illuminated by light of wavelength 5895 Å. Calculate the angular deviation of the second order bright lines.

Ans: $\theta = 13.63^\circ$

(2006 Failures)

Self test: (9)

Q.5 Light of wavelength $6 \times 10^{-7} \text{ m}$ falls normally on a diffraction grating with 400 lines per millimeter. At what angle to the normal are the 1st, 2nd, and 3rd order spectra produced. Ans: $\theta = 13.88^\circ, \theta = 28.68^\circ, \theta = 46.05^\circ$

Self test: (10)

A monochromatic light from helium-neon laser of wavelength 632.8 nm falls normally on a grating with 5000 lines /cm. Find the angles to the normal for 1st and 2nd order maxima.

Q.6 If a diffraction grating produced a 1st order spectrum of light of wavelength $6 \times 10^{-7} \text{ m}$ at an angle of 20° from the normal. What is its spacing and also calculate the number of lines per mm?

(2009 Suppl. 2011 Annual)

Given Data:

$$\text{No. of order} = m = 1$$

$$\text{Wavelength of light} = \lambda = 6 \times 10^{-7} \text{ m}$$

$$\text{Angular deviation} = \theta = 20^\circ$$

$$\text{Length of grating} = 1 \text{ mm} = 1 \times 10^{-3} \text{ m}$$

To Find:

(a) Grating element = d = ?

(b) No. of lines/mm = ?

Solution:

(a) We know that diffraction grating equation

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

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

$$d = \frac{1 \times 6 \times 10^{-7}}{\sin 20^\circ}$$

$$d = \frac{6 \times 10^{-7}}{0.342}$$

$$d = 1.75 \times 10^{-6} \text{ m} \quad \text{Ans.}$$

(b) Length of grating = 1 mm = $1 \times 10^{-3} \text{ m}$

$$d = \frac{\text{Length of grating}}{\text{No. of lines}}$$

$$\text{No. of lines} = \frac{\text{Length of grating}}{d}$$

$$\text{No. of lines} = \frac{1 \times 10^{-3}}{1.75 \times 10^{-6}}$$

$$\text{No. of lines} = 571 \text{ lines/mm} \quad \text{Ans.}$$

Self test: (11)

How many lines per centimeter are there in a grating in which the light of wavelength $4160 \text{ \AA}$ falls normally and a second order spectrum is obtained at an angle of 12° .
(2005 Supp.)

Ans: [2500 lines/cm]

Self test: (12)

When a light of wavelength $6000 \text{ \AA}$ falls on a diffraction grating, it produces a second order spectrum at an angle of 30° from the normal. Find

- (i) The grating element (ii) The number of lines per millimeter.

Ans: [$d = 2.4 \times 10^{-6}$, 417 lines/nm] (2003 P.E)

Self test: (13)

If a diffracting grating produces a first order spectrum of light of wave length $6 \times 10^{-7} \text{ m}$ at an angle of 20° from the normal. Calculate the number of lines per mm.

Ans: (570 lines per mm) (2007)

Q.7 Newton's rings are formed between a lens and a flat glass surface of wavelength $5.88 \times 10^{-7} \text{m}$. If the light passes through the gap at 30° to the vertical and the fifth dark ring is of diameter 9mm. What is the radius of the curvature of the lens?

Given Data:

Wavelength of light	=	λ	=	$5.88 \times 10^{-7} \text{m}$
No. of dark ring	=	m	=	5
Diameter of 5 th dark ring	=	D_5	=	9mm = $9 \times 10^{-3} \text{m}$
Light passes at the angle	=	θ	=	30°

To Find:

Radius of curvature of lens = R = ?

Solution:

$$\gamma_5 = \frac{D_5}{2} = \frac{9 \times 10^{-3}}{2}$$

$$= 4.5 \times 10^{-3} \text{m}$$

For m^{th} dark ring

$$\gamma = \sqrt{\frac{m\lambda R}{\cos \theta}}$$

Squaring both sides

$$\gamma^2 = \frac{m\lambda R}{\cos \theta}$$

$$R = \frac{\gamma^2 \cos \theta}{m\lambda}$$

$$R = \frac{(4.5 \times 10^{-3})^2 \cos 30^\circ}{5 \times 5.88 \times 10^{-7}}$$

$$R = \frac{2.025 \times 10^{-5} \times 0.866}{2.94 \times 10^{-6}}$$

$$R = 5.96 \text{m} \quad \text{Ans.}$$

Q.8 How far apart are the diffracting planes in a NaCl crystal for which X-rays of wavelength $1.54 \text{\AA}$ make a glancing angle of $15^\circ 54'$ in the 1st order?
(2005, 2005 Failure)

Given Data:

Wavelength of X-rays	=	λ	=	$1.54 \text{\AA} = 1.54 \times 10^{-10} \text{m}$
No. of order	=	m	=	1
Glancing angle	=	$15^\circ 54'$	=	$15 + \frac{54}{60} = 15.9^\circ$

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To Find:

Distance between diffracting plane = $d = ?$

Solution:

We know in diffraction of X-rays through crystal is

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

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

$$d = \frac{1 \times 1.54 \times 10^{-10}}{2 \times \sin 15.9^\circ}$$

$$d = \frac{1.54 \times 10^{-10}}{2 \times 0.2739}$$

$$d = \frac{1.54 \times 10^{-10}}{0.5479}$$

$$\boxed{d = 2.81 \times 10^{-10} \text{ m}} \quad \text{Ans.}$$

Self test: (14)

Q.9 A parallel beam of X-rays is diffracted by rocksalt crystal the 1st order maximum being obtained when the glancing angle of incidence is 6 degree and 5 minutes. The distance between the atomic planes of the crystal is $2.81 \times 10^{-10} \text{ m}$. Calculate the wavelength of the radiation.

Ans:

(2009)

Self test: (15)

X - rays of wave length $1.54 \text{ \AA}$ are diffracted by a crystal whose plane are $2.81 \text{ \AA}$ apart. Find the glancing angle for the first order.

(2004)

Ans: $\theta = 15.9^\circ$

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EXTRA PROBLEM:

Q.1. If the diameter of the 10th bright Newton's ring is 0.005m when the light of wavelength 5893Å is used. What is the radius of curvature of the plano convex lens? Also calculated the thickness of the air film correspondy to this lens.
(2003 P.M, 1994)

Given Data:

$$\text{Diameter of 10}^{\text{th}} \text{ bright ring} = D = 0.005\text{m}$$

$$\text{Radius of 10}^{\text{th}} \text{ bright ring} = \frac{D}{2} = \frac{0.005}{2} = 0.0025\text{m}$$

$$\text{Wavelength of light} = \lambda = 5893\text{Å} = 5893 \times 10^{-10}\text{m}$$

$$\text{No. of ring} = N = 10$$

To Find:

$$\text{Radius of curvature} = R = ?$$

$$\text{Thickness of air film} = t = ?$$

Solution:

$$r_N = \sqrt{R(N - \frac{1}{2})\lambda}$$

Squaring both sides

$$r_N^2 = R(N - 0.5)\lambda$$

$$R = \frac{r_N^2}{(N - 0.5)\lambda}$$

$$R = \frac{(0.0025)^2}{(10 - 0.5)5893 \times 10^{-10}}$$

$$R = \frac{0.00000625}{9.5 \times 5893 \times 10^{-10}}$$

$$R = 1.11\text{m} \quad \text{Ans.}$$

$$t = \frac{r^2}{2R}$$

$$t = \frac{(0.0025)^2}{2 \times 1.11}$$

$$t = 2.81 \times 10^{-6}\text{m}$$

Self test: (16)

If the radius of the 14th bright Newton's ring is 1.0mm when the light of wavelength $5.89 \times 10^{-7}\text{m}$ is used. What is the radius of curvature of the lower surface of the lens used. Ans. [0.125m] (2003 Failure) (1999), 2009 Suppl.

Self test: (17)

Determine the wavelength of a monochromatic light used if 14th bright Newton's ring has radius of 1mm when a Plano convex lens of radius of curvature 120mm is used. Ans: [$6.17 \times 10^{-7}\text{m}$] (2001) (1997)

Self test: (18)

If the radius of 14th bright Newton's ring is 1mm and radius of curvature of the lens is 125mm. Calculate the wavelength of light. Ans: [$\lambda = 5.925 \times 10^{-7}\text{m}$] (2010)

Q.2 If the radius of the 12th dark Newton's ring is 1mm when the light of wavelength 5890Å° is used. What is the radius of curvature of the lower surface of the lens used. (2003 P.E)

Given Data:

$$\begin{aligned} \text{Radius of 12}^{\text{th}} \text{ dark ring} &= r = 1\text{mm} = 1 \times 10^{-3}\text{m} \\ \text{Wavelength of light} &= \lambda = 5890\text{Å} = 5890 \times 10^{-10}\text{m} \\ \text{No. of ring} &= m = 12 \end{aligned}$$

To Find:

Radius of mth dark ring

$$r = \sqrt{m\lambda R}$$

Squaring both sides

$$r^2 = m\lambda R$$

$$R = \frac{r^2}{m\lambda}$$

$$R = \frac{(1 \times 10^{-3})^2}{12 \times 5890 \times 10^{-10}}$$

$$R = \frac{1 \times 10^{-6}}{7.068 \times 10^{-6}}$$

$$\boxed{R = 0.141\text{m}} \quad \text{Ans.}$$

Self test: (18)

Determine wavelength of a monochromatic light used if 12th dark Newton's ring is 1mm. When a Plano convex lens of radius of curvature is 141mm is used.

Ans. $[5.91 \times 10^{-7}\text{m}]$

Q.3 Interference fringes were produced by two slits on a screen 0.8m from them when the light of wavelength $5.8 \times 10^{-7}\text{m}$ was used. If the separation between the first and the fifth bright fringes is 2.5mm, Calculate the separation of the two slits. (1995)

Given Data:

$$\begin{aligned} \text{Distance between slits and screen} &= L = 0.8\text{m} \\ \text{Wavelength of light} &= \lambda = 5.8 \times 10^{-7}\text{m} \\ \text{Distance between 1}^{\text{st}} \text{ and 5}^{\text{th}} \text{ bright fringes} &= Y_m = 2.5 \times 10^{-3}\text{m} \end{aligned}$$

To Find:

$$\text{Separation of the slits} = d = ?$$

Solution:

$$Y_m = Y_5 - Y_1$$

$$Y_m = \frac{5L\lambda}{d} - \frac{L\lambda}{d}$$

$$Y_m = \frac{4L\lambda}{d}$$

$$2.5 \times 10^{-3} = \frac{4 \times 0.8 \times 5.8 \times 10^{-7}}{d}$$

$$\boxed{d = 7.424 \times 10^{-4}\text{m}} \quad \text{Ans.}$$

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Self test: (19)

- Calculate the wavelength of light, which illuminates two slits 0.5mm apart and produces an interference pattern on a screen placed 200cm away from the slits. The first bright fringe is observed at a distance of 2.40mm from the central bright image.
($\lambda = 0.6 \times 10^{-6} \text{m}$)

Q.4 Red light falls normally on a diffraction grating ruled 4000 lines/cm and the second order image is diffracted at 34° from the normal compute the wavelength of red light in $\text{\AA}$.
(1996)

Given Data:

$$\begin{aligned}\text{No. of lines} &= 4000 \text{ Lines} \\ \text{Length of grating} &= L = 1 \text{ cm} = 1 \times 10^{-2} \text{ m} \\ \text{No. of order} &= m = 2 \\ \theta &= 34^\circ\end{aligned}$$

To Find:

$$\text{Wavelength of light} = \lambda = ?$$

Solution:

$$\text{Grating element} = d = \frac{\text{Length of grating}}{\text{No. of lines}}$$

$$d = \frac{1 \times 10^{-2}}{4000}$$

$$d = 2.5 \times 10^{-6} \text{ m}$$

We know that grating equation

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

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

$$\lambda = \frac{2.5 \times 10^{-6} \sin 34^\circ}{2}$$

$$\lambda = \frac{1.397 \times 10^{-6}}{2}$$

$$\lambda = 6.989 \times 10^{-7} \text{ m}$$

$$\lambda = 6989 \times 10^{-10} \text{ m}$$

$$\lambda = 6989 \text{ \AA} \quad \text{Ans.}$$

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