Numericals 9

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 5800A°. *(1998)*

Given Data:

Displacement of mirror = x = 0.08mm = 0.08×10^{-3}m

Wave length of light = λ = 5800A° = 5800×10^{-10}m

To Find:

No. of fringes = m = ?

Solution:

We know in Michelson's interferometer

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

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

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

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

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

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

$$m = 275.86$$

$$\boxed{m = 275 \text{ Fringes}}$$ **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. [(5900A°)]*** ***(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 5890A°. ***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 5500A°
Ans.[291 fringes] ***(2007 Supp.)***

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:

Separation of slits	=	d	=	1.9mm	=	1.9×10^{-3}m
Fringe spacing	=	ΔY	=	0.31mm	=	0.31×10^{-3}m
Distance from slits	=	L	=	1m		

To Find:

Wavelength of light = λ = ?

Solution:

Fringe Spacing

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

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

$$\lambda = \frac{0.31\times10^{-3}\times1.9\times10^{-3}}{1}$$

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

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

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)***

Ans.[4.65 x 10^{-7}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:

Separation of slits	=	d	=	0.25mm	=	0.25×10^{-3}m
Distance from the slits	=	L	=	150mm	=	150×10^{-3}m
8 fringes occupy			=	2.62mm	=	2.62×10^{-3}m

To Find:

Wavelength = λ = ?

Solution:

8 fringes occupy = 2.62×10^{-3}m

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

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

Fringe Spacing

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

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

$$\lambda = \frac{0.3275\times10^{-3}\times0.25\times10^{-3}}{150\times10^{-3}}$$

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

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

$$\boxed{\lambda = 5458\text{A}^\circ}$$ **Ans.**

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^{-6}m]*** ***(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^{-8}m]*** ***(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^{-7}m]*** ***(2008)***

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

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

(b) is a 10^{th} order image possible? ***(1998, 2005, 2007 Failures)***

Given Data:

	Wavelength of light =	λ	=	5400A°	=	5400×10^{-10}m
	Length of grating =	L	=	1cm	=	1×10^{-2}m
	No. of lines		=	2000 lines		
(a)	No. of order =	m	=	3		
(b)	No. of order =	m	=	10		

To Find:

Angular deviation = θ = ?

Solution:

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

$$d = \frac{1\times10^{-2}}{2000}$$

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

(a) We know in diffraction grating equation

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

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

$$\sin\theta = \frac{3\times5400\times10^{-10}}{5\times10^{-6}}$$

$$\sin\theta = \frac{1.62\times10^{-6}}{5\times10^{-6}}$$

$$\sin\theta = 0.324$$

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

$$\boxed{\theta = 18.9^\circ}$$ **Ans.**

(b)

$$\sin\theta = \frac{10\times5400\times10^{-10}}{5\times10^{-6}}$$

$$\sin\theta = 1.08$$

Since value of Sin θ can not be greater than 1, therefore 10^{th} order image is impossible.

Self test: (8)

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

Ans: [$\theta = 13.63°$] *(2006 Failures)*

Self test: (9)

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

Self test: (10)

A monochromatic light from helium-neon LASER of wave length 6.328nm falls normally on a grating with 5000 lines /cm. Find the angles to the normal for 1^{st} and 2^{nd} order maxima.

Q.6 If a diffraction grating produced a 1^{st} order spectrum of light of wavelength 6×10^{-7}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:

No. of order	=	m	=	1
Wavelength of light	=	λ	=	6×10^{-7}m
Angular deviation	=	θ	=	20°
Length of grating	=	1mm	=	1×10^{-3}m

To Find:

(a) Grating element = d = ?

(b) No. of lines/mm = ?

Solution:

(a) We know that diffraction grating equation

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

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

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

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

$$\boxed{d = 1.75 \times 10^{-6}\,m}$$ **Ans.**

(b) Length of grating = 1mm = 1×10^{-3}m

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

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

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

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

Self test: (11)

How many lines per centimeter are there in a grating in which the light of wavelength 4160A° falls normally and a second order spectrum is obtain at an angle of 12°. *(2005 Supp.)*

Ans: [2500 lines/cm]

Self test: (12)

When a light of wavelength 6000A° 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 x 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 × 10^{-7} 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 x 10^{-7}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	=	5.88×10^{-7}m		
No. of dark ring	=	m	=	5		
Diameter of 5^{th} dark ring	=	D_5	=	9mm	=	9×10^{-3}m
Light passes at the angle	=	θ	=	30°		

To Find:

Radius of curvature of lens = R = ?

Solution:

$$\gamma_5 = \frac{D_5}{2} = \frac{9\times10^{-3}}{2}$$

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

For m^{th} dark ring

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

Squaring both sides

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

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

$$R = \frac{(4.5\times10^{-3})^2 \cos 30°}{5\times5.88\times10^{-7}}$$

$$R = \frac{2.025\times10^{-5}\times0.866}{2.94\times10^{-6}}$$

$$\boxed{R = 5.96\text{m}}$$ **Ans.**

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

Given Data:

Wavelength of X-rays	=	λ	=	1.54A°	=	1.54×10^{-10}m
No. of order	=	m	=	1		
Glancing angle	=	15°54′	=	$15 + \frac{54}{60}$	=	15.9°

To Find:

Distance between diffracting plane = d = ?

Solution:

We know in diffraction of X-rays through crystal is

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

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

$$d = \frac{1\times1.54\times10^{-10}}{2\times\sin 15.9^\circ}$$

$$d = \frac{1.54\times10^{-10}}{2\times0.2739}$$

$$d = \frac{1.54\times10^{-10}}{0.5479}$$

$$\boxed{d = 2.81 \times 10^{-10}\,m}$$ **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 x 10^{-10}m. Calculate the wavelength of the radiation.

Ans: ***(2009)***

Self test: (15)

X – rays of wave length 1.54A° are diffracted by a crystal whose plane are 2.81A° apart. Find the glancing angle for the first order. ***(2004)***

Ans: [$\theta = 15.9°$]

EXTRA PROBLEM:

Q.1 If the diameter of the 10th bright Newton's ring is 0.005m when the light of wavelength 5893A° 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:

Diameter of 10th bright ring = D = 0.005m

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

Wavelength of light = λ = 5893A° = $5893 \times 10^{-10}\text{m}$

No. of ring = N = 10

To Find:

Radius of curvature = R = ?

Thickness of air film = t = ?

Solution:

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

Squaring both sides

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

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

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

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

$$\boxed{R = 1.11\text{m}}$$ **Ans.**

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

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

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

Self test: (16)

If the radius of the 14th bright Newton's ring is 1.0mm when the light of wavelength 5.89×10^{-7}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: [6.17×10^{-7}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: [$\lambda = 5.925 \times 10^{-7}$ m]***
(2010)

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

Given Data:

Radius of 12th dark ring = r = 1mm = 1×10^{-3}m
Wavelength of light = λ = 5890A° = 5890×10^{-10}m
No. of ring = m = 12

To Find:

Radius of mth dark ring

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

Squaring both sides

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

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

$$R = \frac{(1\times10^{-3})^2}{12\times5890\times10^{-10}}$$

$$R = \frac{1\times10^{-6}}{7.068\times10^{-6}}$$

$$\boxed{R = 0.141\text{m}}$$ **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 x 10^{-7}m]

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

Given Data:

Distance between slits and screen = L = 0.8m
Wavelength of light = λ = 5.8 x 10^{-7}m
Distance between 1st and 5th bright fringes = Y_m = 2.5 x 10^{-3}m

To Find:

Separation of the slits = d = ?

Solution:

$$Y_m = Y_5 - Y_1$$

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

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

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

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

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. *($\lambda = 0.6 \times 10^{-6} m$)*

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 A°. *(1996)*

Given Data:

No. of lines = 4000 Lines

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

No. of order = $m = 2$

$\theta = 34°$

To Find:

Wavelength of light = $\lambda = ?$

Solution:

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

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

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

We know that grating equation

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

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

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

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

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

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

$$\boxed{\lambda = 6989 \text{ A°}}$$ **Ans.**