Course : B.Sc. (H) Physics – Semester II
Subject : Waves and Optics
Paper Code : 32221202

Fraunhofer Diffraction (Practice Sheet)

Books to be referred:

1) Fundamentals of Optics by F. A. Jenkins and H. E. White
2) Optics by Ajoy Ghatak
3) Schaum's Outline Series - Theory and Problems of Optics by Eugene Hecht
4) Principles of Optics by B. K. Mathur

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[1] A parallel beam of monochromatic light of wavelength 5×10^{-5} cm is incident normally on a long narrow slit of width 0.5 mm. Assuming Fraunhofer diffraction, calculate the angles of diffraction corresponding to the first three minima.

(Ans: $0.057°,\ 0.115°, 0.17°$)

[2] A parallel beam of monochromatic light of wavelength 5×10^{-5} cm is incident normally on a long narrow slit of width 0.2 mm. A screen is placed at a distance 3 m from the slit. Assuming Fraunhofer diffraction, calculate the total with of the central maximum.

(Ans: 1.5 cm)

[3] A convex lens of focal length 20 cm is placed after a slit of width 0.6 mm. If a plane wave of wavelength $6000\ A°$ falls normally of the slit, then,

- Calculate the separation between the second minima on either side of the central maximum.

(Ans: 0.08 cm)

- What will be the ratio of intensity of principle maximum to that of the first maxima on either side of the principle maximum?

(Ans: ~22)

[4] A convex lens of focal length 40 cm is placed behind a slit of width 0.45 mm. If a plane wave of wavelength $5461\ A°$ falls normally of the slit, then, calculate the distance of the first minimum from the principle maxima.

(Ans: 0.485 mm)

[5] A monochromatic light of wavelength 600 nm passes through a single slit which has a width of 0.8 nm.

- What should be the distance between slit and the screen so that the first minimum in the diffraction pattern is at a distance of 1.0 mm from the centre of the screen?
- Calculate the width of central maxima.

(Ans: 1.33 m, 2 mm)

[6] A lens, whose focal length is 40 cm, forms a Fraunhofer diffraction pattern of a slit 0.3 mm wide. Calculate the distance of the first dark band and of the next bright band from the axis. Take $\lambda = 5890A^{o}$.

(Ans: 0.785 mm, 1.178 mm)

[7] In Fraunhofer diffraction through a slit of width 0.5 mm and length 3 cm, both the lenses have focal length 50 cm. Assuming wavelength of incident radiation to be 650 nm, compute the location of the first minimum and the first subsidiary maximum from the central axis.

(Ans: 0.65 mm, 0.93 mm)

[8] Consider a set of 2 slits each of width 0.0088 cm and separated by a distance of 0.07 cm. It is illuminated by a monochromatic light source of wavelength 6.328×10^{-5} cm. How many minima will be formed inside the first diffraction minimum?

(Ans: 16 minima between the two first order diffraction minima)

[9] Consider a set of 2 slits each of width 0.05 cm and separated by a distance of 0.1 cm. It is illuminated by a monochromatic light source of wavelength 6.328×10^{-5} cm. If the convex lens of focal length 10 cm is placed beyond the slit, then,

- How many minima will be formed inside the first diffraction minimum?
- Calculate the position of the minima inside the first diffraction minimum.

(Ans: 0.0316 mm, 0.094 mm)

[10] In 2-slit Fraunhofer diffraction, consider that each slit has a width of 0.17 mm. The separation between their centres is 0.85 mm. Will there be any missing order? If yes, then which ones?

(Ans: 5, 10, 15…)

[11] In Fraunhofer diffraction pattern of a double slit under wavelength 650 nm illumination appears in the back focal plane of a lens having focal length of 80 cm. The centre to centre separation between the bright fringes is 1.04 mm and the fifth maximum is missing. Determine the width of each slit and the distance between them

(Ans: 0.5 mm, 0.1 mm)

[12] In an N-slit Fraunhofer diffraction pattern, show that the principal maximum becomes sharper as N increases.

[13] Consider a diffraction grating with 15000 lines per inch. Show that if we use a white light source, then,

- First and second order spectra will never overlap.
- Second and third order spectra will overlap.

[14] Consider a diffraction grating with 15000 lines per inch. What will be the angular separation of D_1 and D_2 lines of sodium in the second order spectra?

(Ans: 3.44 minute)

[15] What is the maximum width of any clear space in a grating having 15000 lines per inch, if complete second order spectrum is to be formed?

(Ans: 0.845×10^{-4}cm)

[16] How many spectral orders will be visible if radiation of wavelength $5000\ A^o$ is incident on a diffraction grating having 2620 lines per inch?

(Ans: 19)

[17] A diffraction grating used at normal incidence gives a green line ($\lambda = 5400\ A^o$) in a certain order superimposed on the violet line ($\lambda = 4050\ A^o$), of the next order. If the angle of diffraction is 30^o, how many lines are there per cm of the grating?

(Ans: 3086)

[18] What is the angular separation between the sodium D lines (589.592 nm and 588.995 nm) in the first order spectrum generated by a plane transmission grating having 10000 lines per inch at normal incidence?

(Ans: 2.42×10^{-4} rad)

[19] Calculate the least width that a diffraction grating must have in order to resolve two components of the sodium D line in the second order. It is given that the grating has 800 lines per cm, $\lambda_1 = 5896\ A^o$ and $\lambda_2 = 5890\ A^o$.

(Ans: 0.615 cm)

[20] How many lines must be ruled on a transmission grating so that it will just resolve the sodium doublet (589.592 nm and 588.995 nm) in the first order spectrum?

(Ans: 988)

[21] A transmission grating of 16000 lines per inch is 2.5 inch wide. Operating at wavelength (λ) of 550 nm,

- What is the resolving power in the third order?
- Calculate the minimum resolvable $\Delta\lambda$ in the second order.

(Ans: 120000, 6.88×10^{-3} nm)

[22] Calculate the radii of the first two dark rings of Fraunhofer diffraction pattern produced by a circular aperture of radius 0.02 cm at the focal plane of a convex lens of focal length 20 cm. Assume wavelength 6×10^{-5} cm.

(Ans: 0.036 cm, 0.067 cm)

[23] A circular aperture of radius 0.01 cm is placed in front of a convex lens of focal length 25 cm and is illuminated by a monochromatic light source of wavelength 5×10^{-5}cm. Calculate the radii of the first three dark rings.

(Ans: 0.76 mm, 1.4 mm, 2.02 mm)

[24] A plane wave of wavelength $6000\ A°$ is incident on a convex lens of diameter 5 cm and focal length 10 cm. Calculate the radius of the first dark ring on the focal plane of the lens.

(Ans: 1.46×10^{-4}cm)

[25] The refracting telescope at the Lick Observatory is a 36-inch, 56-foot focal length instrument. Compute the radius of the second bright ring in the Airy pattern of a star formed on the focal plane of the objective.
(Ans: 0.0275 mm)