

Topics are **Interference, Diffraction and Fourier Optics.**

**Due Tuesday 03/03/08.** We can discuss solutions during **two Sunday afternoon problem sessions** (02/23/08 and 03/01/08)

**REMEMBER: Midterm is either** Tuesday 03/03/08 7-9M **or** Wednesday 03/04/08 7-9PM in SC L26. **Closed book.**

**Readings:** Boccio

[http://chaos.swarthmore.edu/courses/Physics50\\_2009/008\\_InterferenceDiffraction.pdf](http://chaos.swarthmore.edu/courses/Physics50_2009/008_InterferenceDiffraction.pdf)

[http://chaos.swarthmore.edu/courses/Physics50\\_2009/009\\_FourierOptics.pdf](http://chaos.swarthmore.edu/courses/Physics50_2009/009_FourierOptics.pdf)

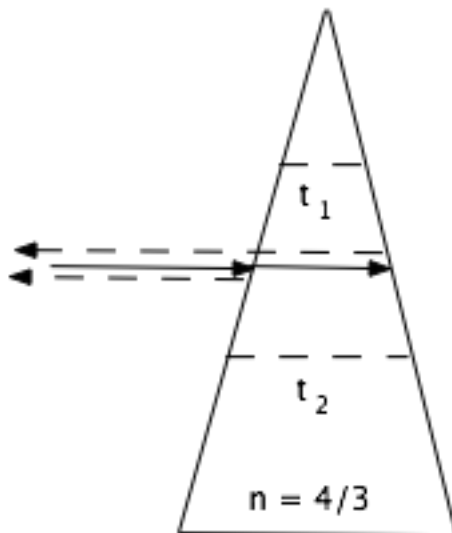
[http://chaos.swarthmore.edu/courses/Physics50\\_2009/010\\_ScalarDiffractionTheory.pdf](http://chaos.swarthmore.edu/courses/Physics50_2009/010_ScalarDiffractionTheory.pdf)

**Other Readings (elementary level)**

[http://chaos.swarthmore.edu/courses/Physics50\\_2009/008A\\_Diffraction\\_Ch37.pdf](http://chaos.swarthmore.edu/courses/Physics50_2009/008A_Diffraction_Ch37.pdf)

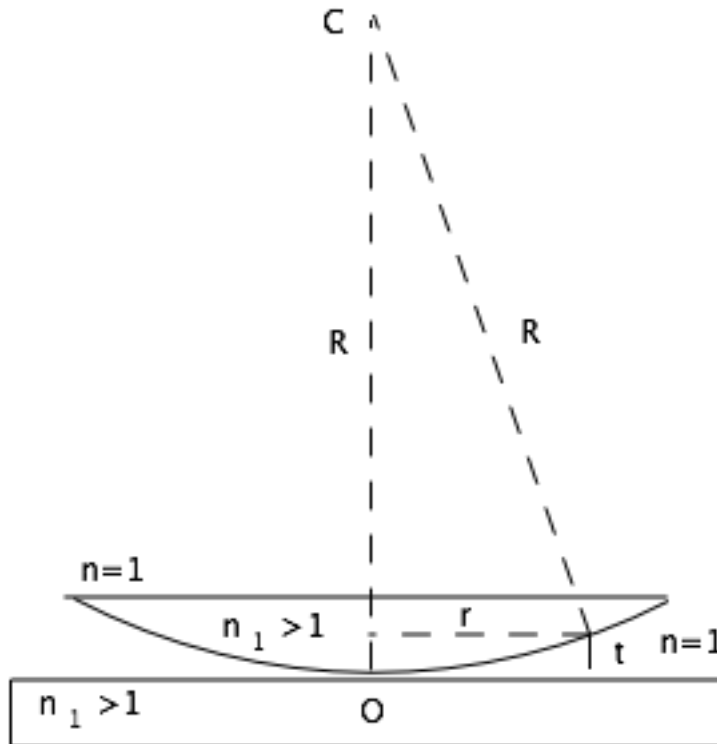
### **Problem 1 - A wedge-shaped soap film**

A monochromatic beam of light ( $\lambda = 6 \times 10^{-7} \text{ m} = 0.6 \mu$ ) is incident on a wedge-shaped soap film ( $n = 4/3$ ). Because the variation of the thickness  $t$  is very small, the direction of the incident beam can be assumed to be normal to the surface of the soap film as shown below. If the light reflects off the first surface (1) and also off the second surface (2), find the thickness difference between two consecutive light or dark fringes. Note that there is an extra phase difference of  $\pi$  due to reflection at the the first surface of the film, i.e., between a lower refractive index (air) and a higher refractive index (film).



## Problem 2 - Newton's Rings

A planoconvex lens lies on a flat surface of a plate. Both have the same refractive index  $n_1$ . The radius of the lens is  $R=6.2$  m. A beam of monochromatic light ( $\lambda=6.43\times 10^{-7}m=0.643\mu$ ), incident on the plane surface of the lens, forms a system of circular fringes around a point of contact  $O$  as shown below. Are the fringes dependent on the refractive index  $n_1$ ? Give a simplified ray tracing outlining where the two reflected rays that cause interference start. For the first 10 dark circular fringes find the corresponding thicknesses  $t$ , the radii  $r$  and the differences between a value of  $r$  and the preceding one. Make plots of the radii  $r$ , of their differences and of the thicknesses  $t$  as functions of the order  $m$  of the fringes.



### Problem 3 - Spherical wave and plane wave

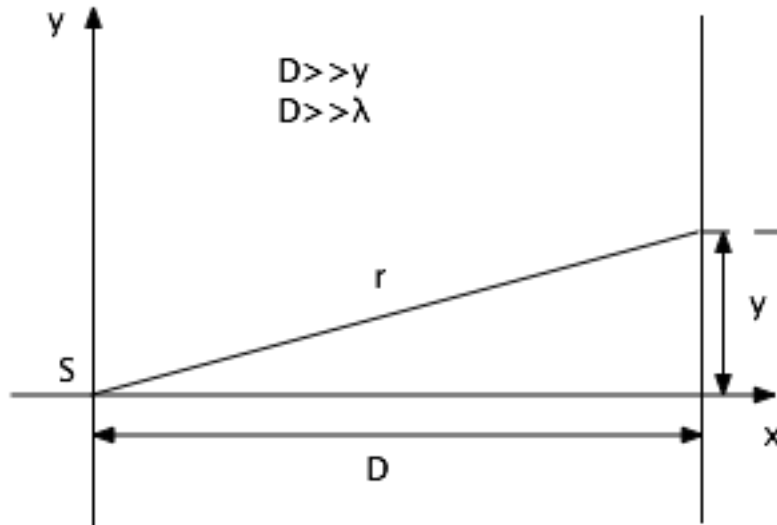
A point source S located at the origin of a coordinate system emits a spherical sinusoidal wave in which the electric field  $E_1$  is given by

$$E_1 = A \left( \frac{D}{r} \right) \cos \left( \omega t - \frac{2\pi r}{\lambda} \right)$$

where  $r$  is the distance from S (see figure below). In addition, there is a plane wave propagating along the x-axis. This wave is given by

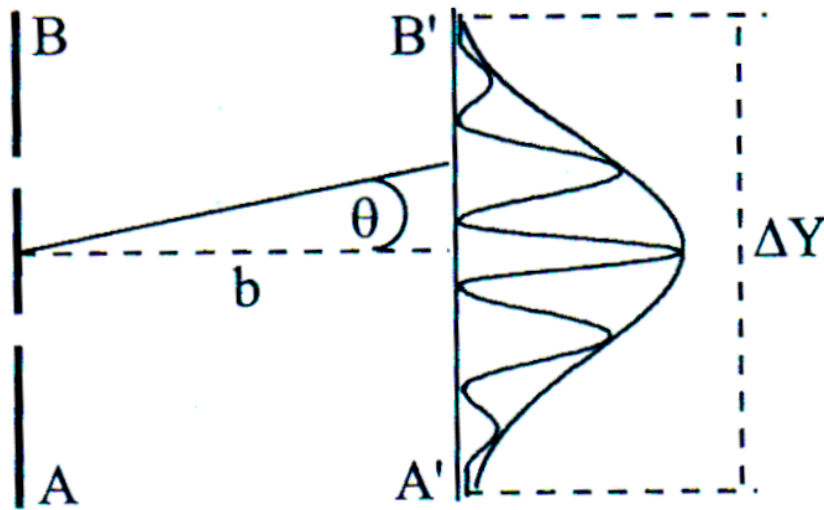
$$E_2 = A \cos \left( \omega t - \frac{2\pi x}{\lambda} \right)$$

(Note: we treat both  $E_1$  and  $E_2$  as scalar waves in this problem). Both waves are incident on a flat screen as shown. Compute the resultant intensity  $I$  at the screen as a function of the distance  $y$  from the x-axis for values of  $y$  small compared with  $D$ . Express  $I$  in terms of  $y$ ,  $D$ ,  $\lambda$  and the intensity  $I_0$  at  $y = 0$ .



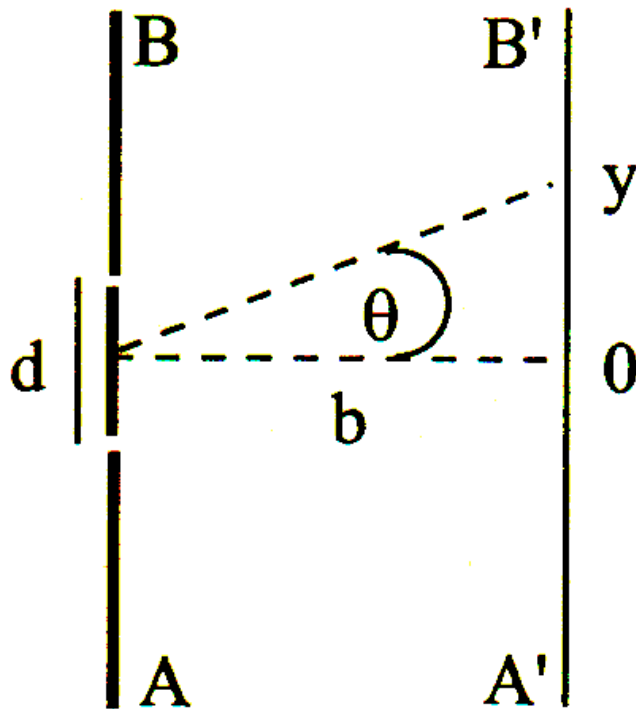
**Problem 4 - Two-slit interference 1**

A beam of monochromatic light ( $\lambda = 0.5\mu$ ) is incident normally on a plane A-B containing two slits. The slits are  $d = 0.1$  mm apart and  $h = 0.04$  mm wide. The screen A'-B' is a distance of 1 m from the slits as shown below. Verify that there are 5 fringes between the two minima of diffraction order  $m = 1$ . Find the relative intensity of the fringe of of the 2nd order of interference.



**Problem 5 - Two-slit interference 2**

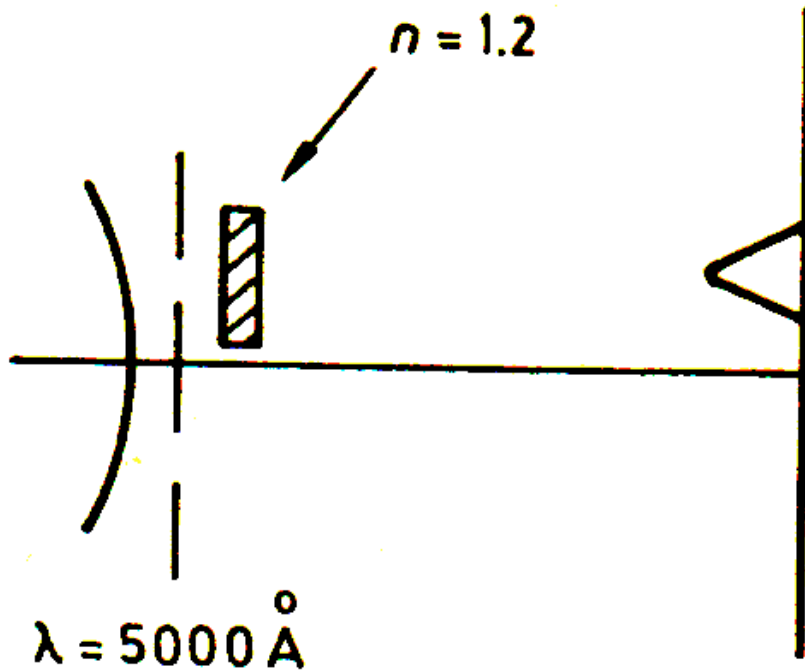
A beam of monochromatic light ( $\lambda = 0.5\mu$ ) is incident normally on a plane A-B containing two slits. The slits are  $d = 0.1$  mm apart. The screen A'-B' is a distance of 1 m from the slits as shown below and the bright fringe of order  $m = 1$  is a distance  $y$  from the origin O. If a thin transparent film of refractive index  $n$  and thickness  $s = 0.02$  mm covers the lower slit, then this bright fringe is shifted to  $y^* = y - 13$  mm from the origin. Also the bright fringe of order  $m = 0$  assumes a new position  $y_0$  from the origin. Find the values of  $y$ ,  $y^*$ ,  $y_0$  and the value of the refractive index  $n$ .



**Problem 6 - Two-slit interference 3**

A two-slit interference experiment is illustrated below;

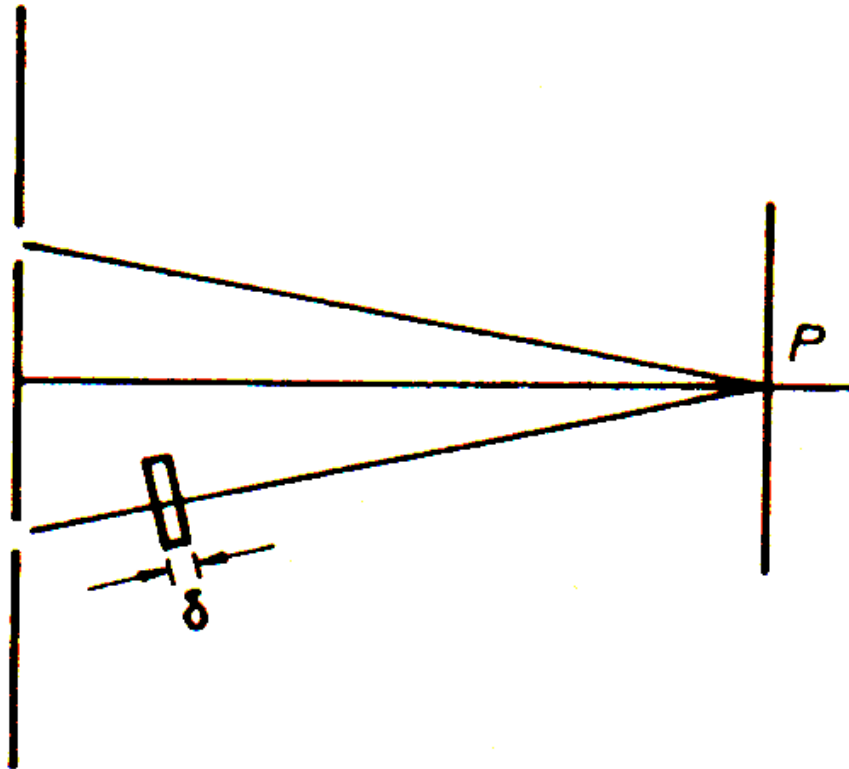
$\lambda = 5000 \text{ \AA}$ . When a thin film of a transparent material is put behind one of the slits, the zero order fringe moves to the position previously occupied by the 4th order bright fringe. The index of refraction of the film is  $n = 1.2$ . Calculate the thickness of the film.



### Problem 7 - Two-slit interference 4

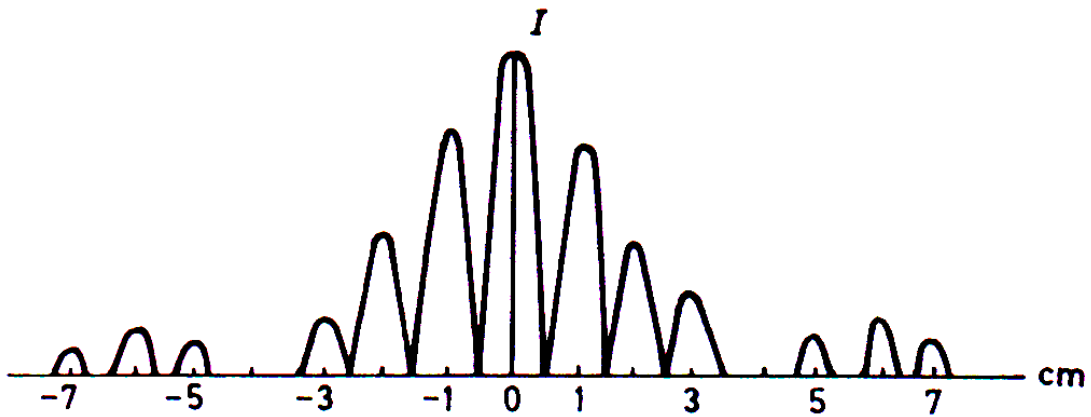
The diagram below shows a double-slit experiment in which coherent monochromatic light of wavelength  $\lambda$  from a distant source is incident upon two slits, each of width  $w$  ( $w \gg \lambda$ ), and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness  $\delta$ , index of refraction  $n$ , is placed between one of the slits and the screen perpendicular to the light path. Assume that the glass does not absorb or reflect any light. If the intensity for  $\delta=0$  is given by  $I_0$ :

- What is the intensity at point P as a function of thickness  $\delta$ ?
- For what values of  $\delta$  is the intensity at P a minimum?
- Suppose the width  $w$  of one of the slits is now increased to  $2w$ , the other width remaining unchanged. What is the intensity at point P as a function of thickness  $\delta$ ?



**Problem 8 - Two-slit interference 5**

A plane wave of light from a laser has a wavelength of  $\lambda = 6000 \text{ \AA}$ . The light is incident on a double slit. After passing through the double slit, the light falls on a screen 100 cm beyond the double slit. The intensity distribution of the interference pattern on the screen is shown below. What is the width of each slit and what is the separation between the two slits?



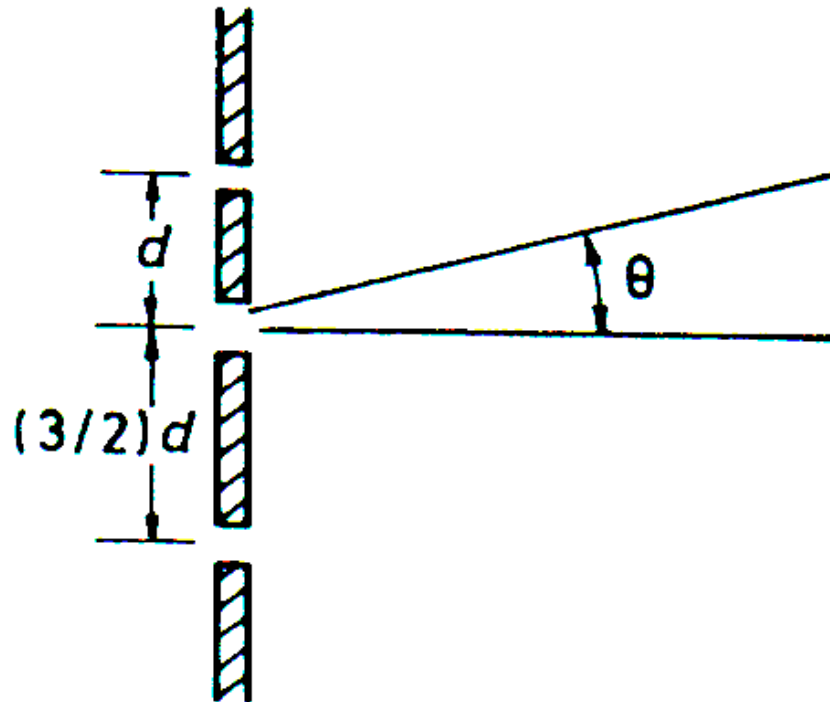


### Problem 9 - Three-slit interference 1

We have the three slits shown below. Assume the openings of the individual slits are the same ( $\leq \lambda/2$ ).

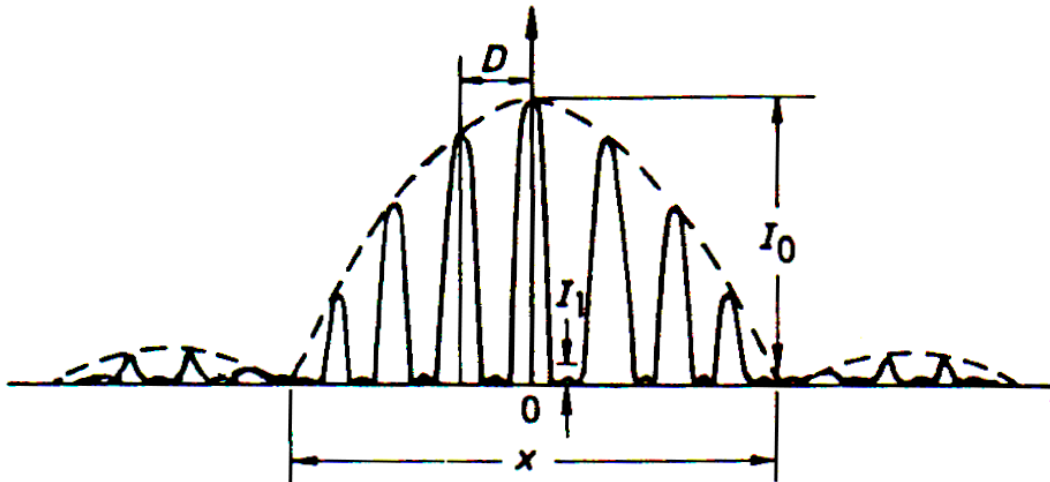
Consider the corresponding interference pattern:

- (a) At what value of  $\theta$  is the first principal maximum?
- (b) Let the result of (a) be called  $\theta_1$ . What is the ratio of the intensity at  $\theta_1/2$  to the intensity at  $\theta=0$ ?



**Problem 10 - Three-slit interference 2**

Shown below is the Fraunhofer diffraction pattern resulting from 3 slits. The slit widths are  $w$ , slit separation is  $d$ , the distance between the screen and slits is  $f$ , and the wavelength of the light is  $\lambda$ . Obtain expression for  $x$ ,  $D$ , and  $I_0/I_1$  in terms of the parameters of the experiment.



**Problem 11 - Five-slit interference**

Consider an opaque screen with 5 equally spaced narrow slits (spacing =  $d$ ) and with monochromatic plane-wave light (wavelength  $\lambda$ ) incident normally. Draw a sketch of the transmitted intensity versus angle to the normal for  $\theta=0$  to approximately  $\theta=1/5$  radian. Your sketch should show the maxima and minima of intensity. Approximately what is the ratio of intensity of the least intense to the most intense peak? Approximately what is the angular distance of the first intense peak away from  $\theta=0$ ?

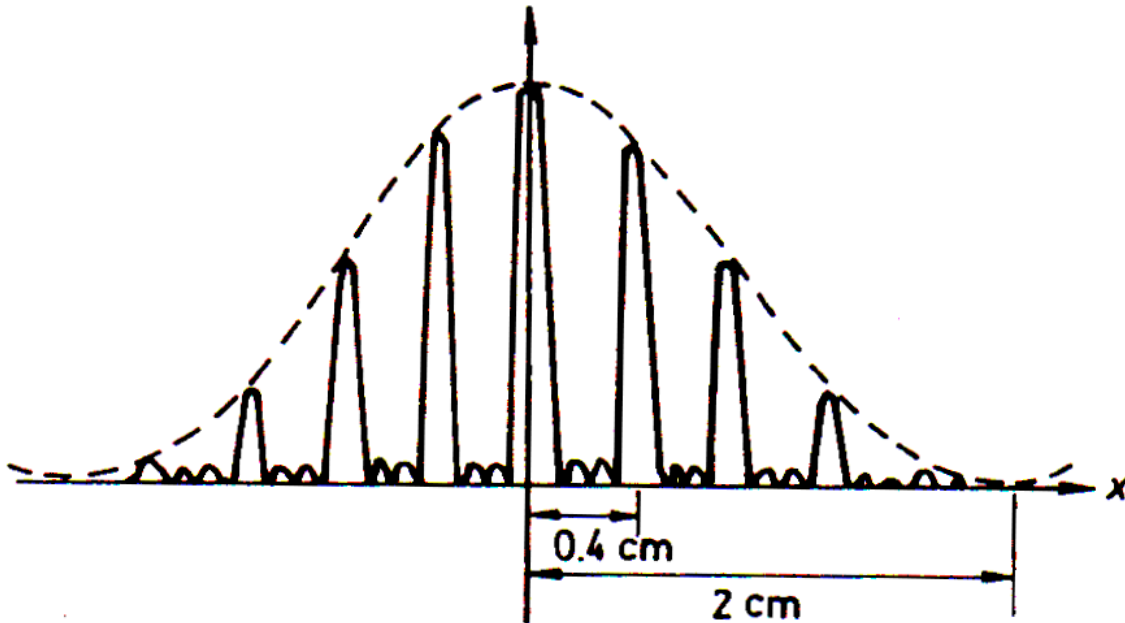
**Problem 12 - N-slit interference 1**

A beam of monochromatic light ( $\lambda=0.58958\mu$ ) is incident normally on a grating composed of  $N = 1000$  equidistant parallel and linear slits. The distance between the slits is  $d=8\mu$  and each slit has a width of  $h=2\mu$ . Find the angular positions and relative intensity of the "lines" included between angular position  $0^\circ$  and that corresponding to the first minimum of the diffraction pattern. What is the intensity of the fourth order "line"?

**Problem 13 - N-slit interference 2**

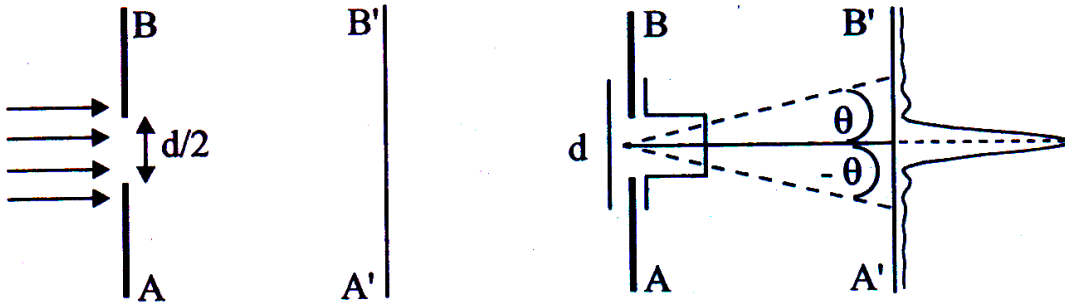
The pattern of intensity  $I$  versus position  $x$  (shown below) is measured on a wall 20 meters from a set of  $N$  identical, parallel slits. Light of wavelength  $\lambda = 6000 \text{ \AA}$  passes through the slits, each of which has width  $a$ , and which are spaced from each other by a distance  $d$ .

- (a) What are the values of  $N$ ,  $a$  and  $d$ ? Give a reason for each answer.
- (b) Give an expression for the dashed curve which is the envelope for the large maxima and explain its physical significance.



### Problem 14 - Fourier Version of Single Slit

A beam of monochromatic light ( $\lambda = 0.5\mu$ ) is incident normally on a plane A-B where there is a single linear slit of width  $d/2 = 0.05$  mm. Assume that the intensity of the wave reaching the slit has unit magnitude. As we know the diffraction pattern on the screen A'-B' is given by the square of the appropriate sinc function as shown below. Find this result using the Fourier series and the Fourier transform.



**Problem 15 - Fourier Version of 5 Slits**

beam of monochromatic light ( $\lambda=0.5\mu$ ) is incident normally on a grating formed by 5 slits as shown below. The distance between the slits is  $d = 0.01$  mm and the width of each slit is  $h = 0.005$  mm. Assume that the intensity of the wave reaching the slit has unit magnitude. Find the Fourier transform of the slits and compute the intensity on the screen where fringes appear in the angular interval  $(-1.5^\circ, 1.5^\circ)$ . Compare the results with the relative intensity found from the standard diffraction formula for  $N = 5$ .

