Instructor, A **section 118**

SFU Department of Physics

phys102q – Fall 2004 – Assignment 9.

Due Thr, Dec 2, 2004 at 23:59hrs. CAPA ID is **5049**

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1. [1 pt.] Light of wavelength 485nm falls on a wall with two slits 0.128mm apart. The n=3 maximum appears 18.0cm from the central maximum (n=0) on a photographic plate. How far is this photographic plate from the wall?

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2. [1 pt.] Two identical rectangular pieces of glass are laid on top of one another on a plane surface. A thin strip of paper is inserted between them at one end, so that a wedge of air is formed. The plates are illuminated by perpendicularly incident light of wavelength 568nm, and 17 interference fringes per 8cm of wedge appear. (i.e. 17 maxima and 17 minima per 8cm of wedge.) What is the angle of the wedge?

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3. [1 pt.] White light reflected at perpendicular incidence from a uniform soap film has an interference maximum at 480nm and a minimum at 450nm, with no minima between 480nm and 450nm. If n=1.30 for the film, what is the film thickness?

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4. [1 pt.] If a thin film of soap (n=1.37) hanging in the air reflects dominantly red light (649nm) What is the minimum thickness of the film?

5. [1 pt.] Now this film is on a sheet of glass, (n=1.49). What is the longest wavelength that will now be predominantly reflected?

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6. [1 pt.] Light of two different wavelengths, λ_1 and λ_2, is incident on a double slit. On a distant screen, the n=16 maximum of λ_1 overlaps the n=15 maximum of λ_2. What is the value of the relative difference $(\lambda_1-\lambda_2)/\lambda_1$ of the wavelengths in this scenario? (Note, n=0 refers to the central maximum.)

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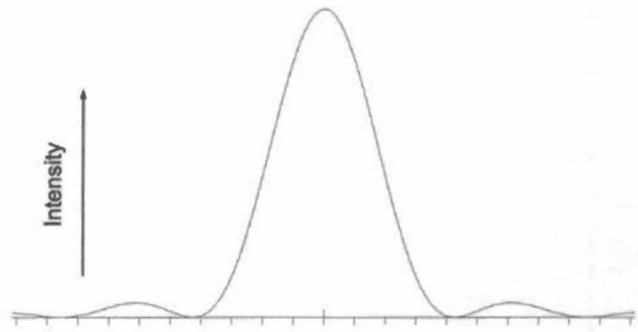
7. [1 pt.] A single vertical slit of width 29μm is located 2.10m from a screen. The intensity pattern below is observed. The distances on the screen can be measured from the scale. Each tick mark is equal to 1cm. What is the wavelength of the light?



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8. [1 pt.] A diffraction grating with 14500 lines per 2.54cm (i.e., per inch) is used to view the visible spectrum from a Hydrogen gas excited by an electrical discharge. At what angle from the beam axis will the first order peak for the blue/green photons with wavelength of 0.486μm occur?

9. [1 pt.] At what angle from the beam axis will the second order peak for the violet photons with wavelength of 0.410μm occur?

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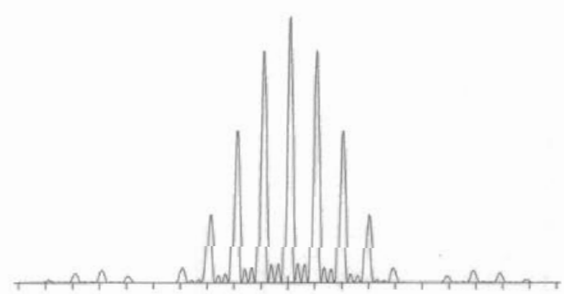
10. [1 pt.] A set of narrow vertical slits is located a distance D from a screen. The slits are equally spaced and have the same width. The intensity pattern in the figure is observed when light from a laser passes through the slits, illuminating them uniformly. The screen is perpendicular to the direction of the light. What is the spacing between the slits? Data: Distance to the screen = 2.23 *meters*; Wavelength of light = 0.470 *micrometers*; Distance between tick marks on the intensity figure = 1.40 *centimeters*



11. [1 pt.] Calculate the width of the slits.

12. [1 pt.] If the slits' separation is increased by a factor of 3, what would be the distance between the principal peaks on the screen?

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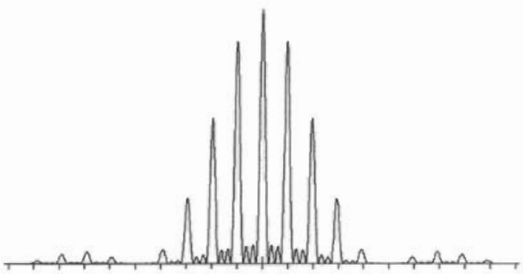
13. [1 pt.] A set of narrow vertical slits is located a distance D from a screen. All the slits have the same width, equal to 24.7 *micrometers*. The intensity pattern in the figure is observed when light from a laser passes through the slits, illuminating them uniformly. How many slits are illuminated?



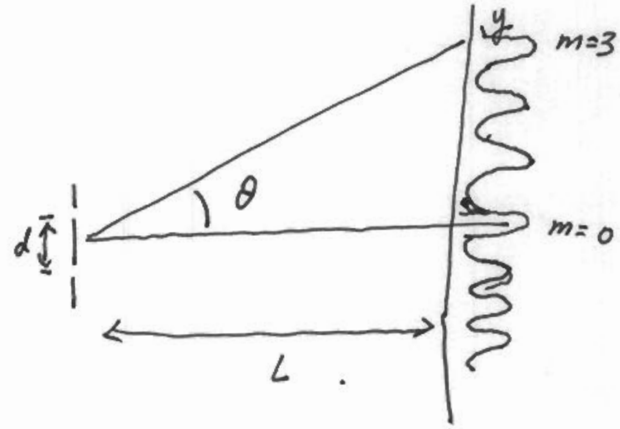
14. [1 pt.] The wavelength of the laser light is 0.566 *micrometers*, and each tick mark on the intensity pattern corresponds to a distance of 1.45 *centimeters*. What is the distance to the screen?

Baking Tip: Kosher salt, iodized salt, sea salt, or a non-sodium containing salt substitute may be used for table salt in baking.

Physics 102.

CAPA set 9 solutions

1. 2-slit interference.



$\lambda = 485$ nm, $d = 0.128$ mm

3rd maximum: $y = 18.0$ cm.

$$d \cdot \sin\theta = 3\lambda$$

$$\theta = \sin^{-1}\frac{3\lambda}{d}.$$

$$L = \frac{y}{\tan\theta} = \frac{y}{\tan\left(\sin^{-1}\frac{3\lambda}{d}\right)} = \frac{0.018}{\tan\left(\sin^{-1}\frac{3\times 485\times 10^{-9}}{1.28\times 10^{-4}}\right)} = 15.8 \text{ m}.$$

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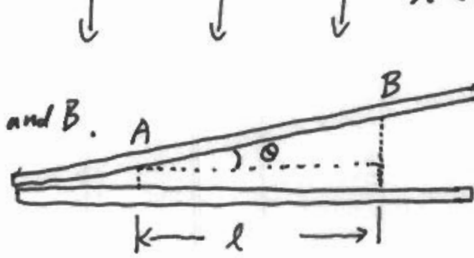
2. Air Wedge



$l = 8$ cm

There are $N=17$ fringes between A and B.

at A: $2d_A + \frac{\lambda}{2} = m\lambda$. ①

at B: $2d_B + \frac{\lambda}{2} = (m+N)\lambda$. ②

$$\tan\theta = \frac{d_B - d_A}{l}$$

② - ①: $2(d_B - d_A) = N\lambda$.

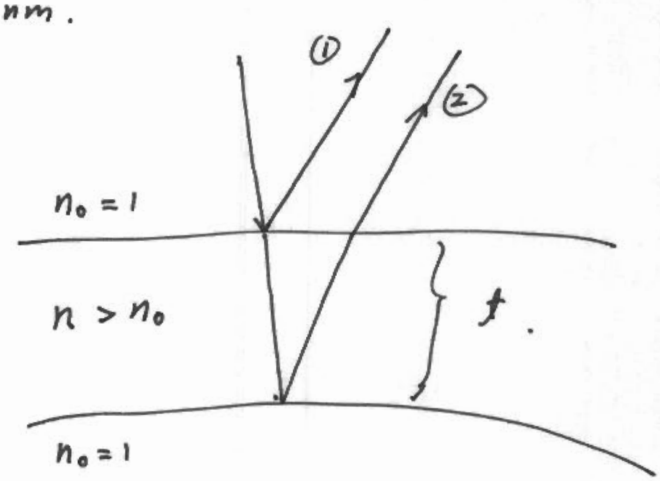
$$\tan\theta = \frac{d_B - d_A}{l} = \frac{N\lambda}{2l} = \frac{17\times 568\times 10^{-9}}{2\times 0.08} = 6.035\times 10^{-5}.$$

$$\theta = \tan^{-1}(6.035\times 10^{-5})$$

$$\theta = 3.46\times 10^{-3} \text{ (degrees)}$$

3. $\lambda_{max} = 480\ nm$, $\lambda_{min} = 450\ nm$.

$n = 1.30$.



Phase angle:

Ray ①:

$\bar{\Phi}_1 = \pi$ due to reflection

Ray ②:

$\bar{\Phi}_2 = 2t \cdot k$ Due to traveling by a distance of $2t$

$= 2t \dfrac{2\pi}{\lambda_n}$

$= \dfrac{4\pi n t}{\lambda_0}$

Phase difference between Ray ① and Ray ②:

$$\Delta\bar{\Phi} = \bar{\Phi}_2 - \bar{\Phi}_1 = \frac{4\pi n t}{\lambda_0} - \pi = \left(\frac{4nt}{\lambda_0} - 1\right)\pi .$$

Max: $\left(\dfrac{4nt}{\lambda_{max}} - 1\right)\pi = 2m\pi$, $\dfrac{4nt}{\lambda_{max}} = 2m+1$ $(m = 0, 1, 2, \cdots)$

Min: $\left(\dfrac{4nt}{\lambda_{min}} - 1\right)\pi = (2l+1)\pi$ $\dfrac{4nt}{\lambda_{min}} = 2l$ $(l = 1, 2, \cdots)$

Choose $l = m+1$. ($\because \lambda_{min} < \lambda_{max}$, $2l > 2m+1$).

$$\frac{4nt}{\lambda_{min}} = 2m+2 = \frac{4nt}{\lambda_{max}} + 1 .$$

$$\frac{4nt}{\lambda_{min}} - \frac{4nt}{\lambda_{max}} = 1 .$$

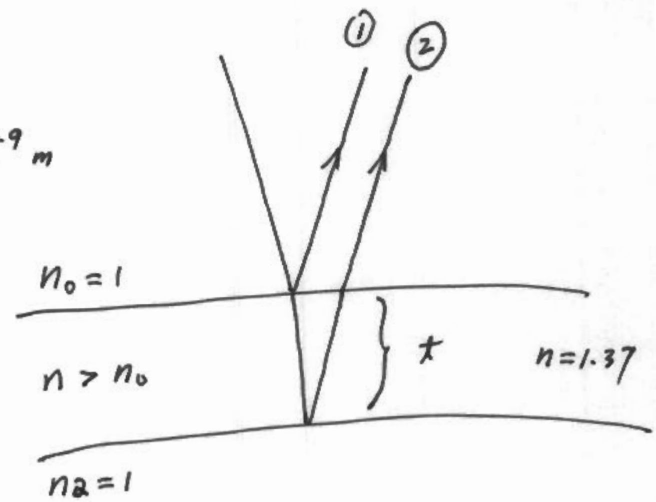
$$t = \frac{1}{4n\left(\frac{1}{\lambda_{min}} - \frac{1}{\lambda_{max}}\right)} = 1.38 \times 10^{-6}\ m .$$

Note: m is supposed to be an integer. However, the algebraic procedure does not reflect that. (Here $m = 7$)

In fact, some students are given data values that lead to a non-integer m value, which means there is no solution.

4.

Constructive interference: $\lambda_{max} = 649 \times 10^{-9}$ m



$$\frac{4nt}{\lambda_{max}} = 2m + 1$$

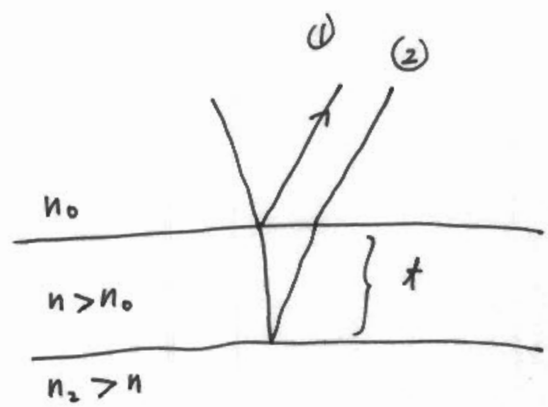
$$4nt = (2m+1)\lambda_{max}$$

$$t = \frac{(2m+1)\lambda_{max}}{4n}$$

$$t_{min} = \frac{\lambda_{max}}{4n} = \frac{649 \times 10^{-9}}{4 \times 1.37} = 1.18 \times 10^{-7} \text{ m}.$$

5.

Now $n_2 = 1.49$.



Phase of Ray ①:

$$\Phi_1 = \pi$$

Phase of Ray ②:

$$\Phi_2 = 2t \cdot k + \pi = \frac{4nt\pi}{\lambda_0} + \pi.$$

phase difference:

$$\Delta\Phi = \Phi_2 - \Phi_1 = \frac{4n\pi t}{\lambda_0}$$

Constructive interference:

$$\frac{4n\pi t}{\lambda_0} = 2m\pi.$$

$$\lambda_0 = \frac{4n\pi t}{2m\pi} = \frac{2nt}{m}$$

longest λ_0: $m = 1$.

$$\lambda_0 = 2nt.$$

$$= 2 \times 1.37 \times 1.18 \times 10^{-7}$$

$$= 3.24 \times 10^{-7} \text{ m}.$$

6. 2-slit interference.

Constructive interference: $d \cdot \sin\theta = m\lambda$.

for λ_1, $m=16$: $d \cdot \sin\theta = 16\lambda_1$ ①

for λ_2, $m=15$: $d \cdot \sin\theta = 15\lambda_2$ ②

①/②: $1 = \frac{16}{15} \cdot \frac{\lambda_1}{\lambda_2}$: $\frac{\lambda_1}{\lambda_2} = \frac{15}{16}$. $\frac{\lambda_2}{\lambda_1} = \frac{16}{15}$

$\therefore \frac{\lambda_1 - \lambda_2}{\lambda_1} = 1 - \frac{\lambda_2}{\lambda_1} = 1 - \frac{16}{15} = -\frac{1}{15} \approx -0.0667$.

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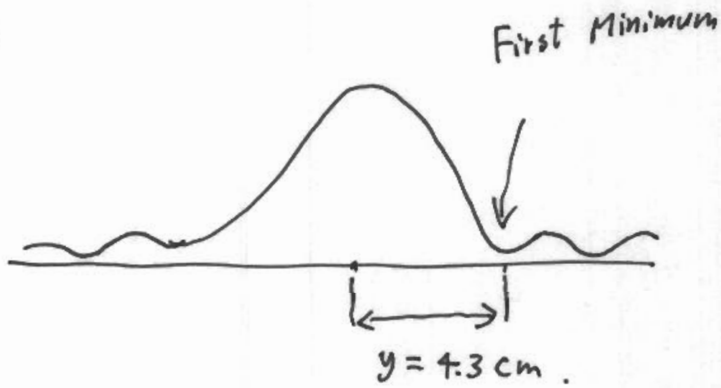
7. Single slit diffraction

$W = 29\ \mu m$

$L = 2.1\ m$. $\frac{y}{L} = \tan\theta$

$y = 4.3\ cm$.



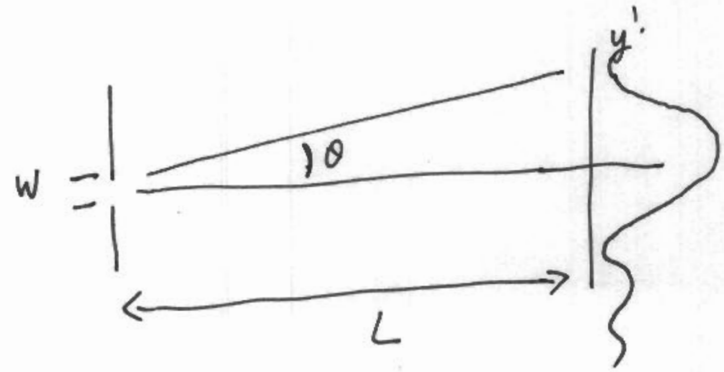
First minimum:

$W \sin\theta = \lambda$

$\lambda = W \sin\left[\tan^{-1}\frac{y}{L}\right]$

$= 2.9 \times 10^{-5} \cdot \sin\left(\tan^{-1}\frac{0.043}{2.1}\right)$

$\approx 5.94 \times 10^{-7}\ m$.

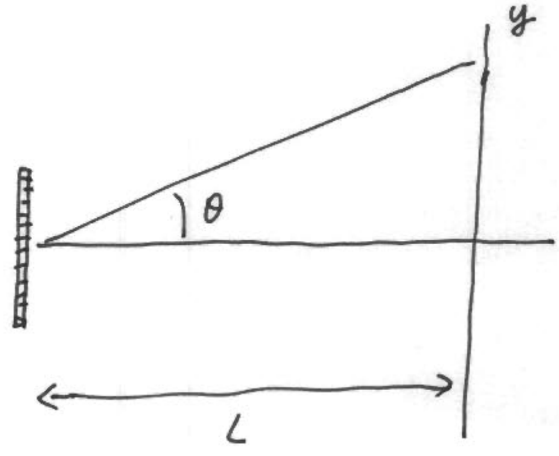


8. Diffraction grating

slit spacing: $d = \frac{2.54\ cm}{14500} = 1.752 \times 10^{-6}\ m$

wavelength: $\lambda = 0.486\ \mu m$.

Principal max: $d \cdot \sin\theta = m\lambda$.



$m=1$: $d \cdot \sin\theta = \lambda$.

$\theta = \sin^{-1}\frac{\lambda}{d}$

$= \sin^{-1}\frac{0.486 \times 10^{-6}}{1.752 \times 10^{-6}}$

$= 16.1°$

9. $m=2$, $\lambda = 0.410\ \mu m$.

$\theta = \sin^{-1}\frac{2\lambda}{d} = \sin^{-1}\frac{2 \times 0.41 \times 10^{-6}}{1.752 \times 10^{-6}} = 27.9°$.

Multi-slit interference.

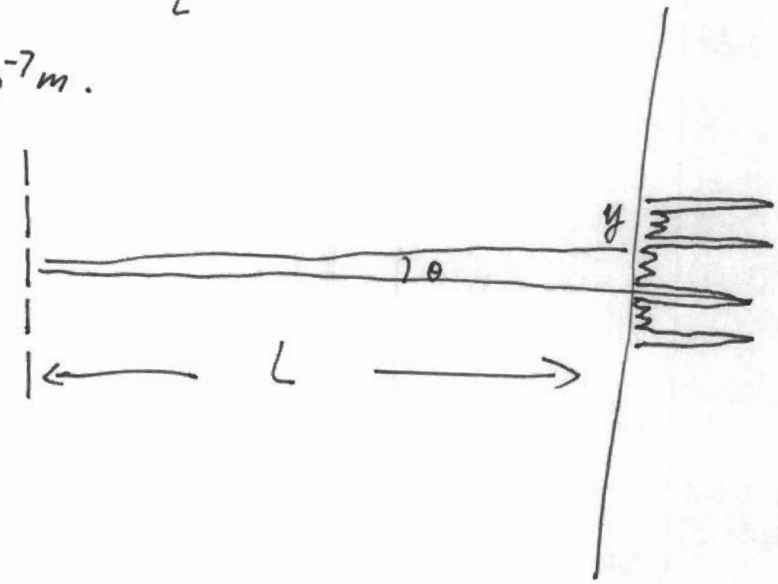
10. $d \cdot \sin\theta = \lambda$.

$\frac{y}{L} = \tan\theta$

$y = 1.4\ cm = 0.014\ m$.

$\lambda = 0.470\ \mu m = 4.70 \times 10^{-7} m$.

$L = 2.23\ m$.



principal Max:

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

$$= \frac{\lambda}{\sin\left(\tan^{-1}\frac{y}{L}\right)}$$

$$= \frac{\lambda}{\sin\left(\tan^{-1}\frac{0.014}{2.23}\right)} = 74.87\ \mu m = 74.9\ \mu m$$

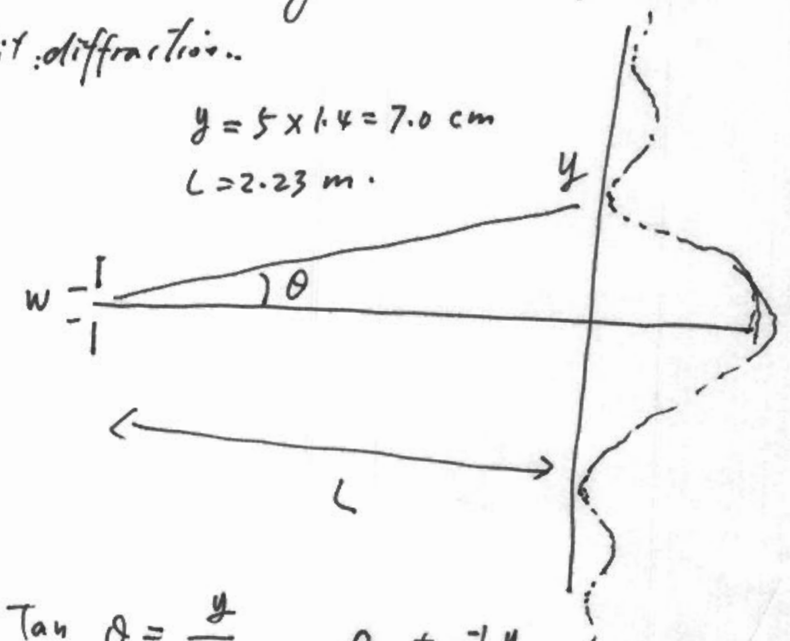
11. Overall shape of the pattern is determined by single-slit diffraction.

First minimum of single slit diffraction.

$y = 5 \times 1.4 = 7.0\ cm$

$L = 2.23\ m$.

$W \sin\theta = \lambda$.



$$W = \frac{\lambda}{\sin\theta}$$

$$= \frac{\lambda}{\sin\left[\tan^{-1}\frac{y}{L}\right]}$$

$$= \frac{4.7 \times 10^{-7}}{\sin\left(\tan^{-1}\frac{0.07}{2.23}\right)}$$

$= 1.498 \times 10^{-5}\ m$.

$\approx 15.0\ \mu m$.

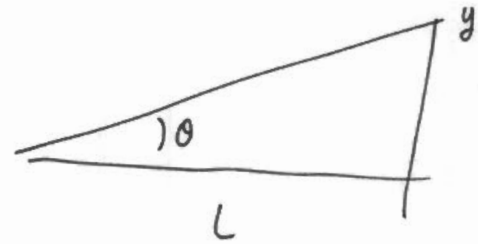
$\tan\theta = \frac{y}{L}$. $\theta = \tan^{-1}\frac{y}{L}$

12. Principal peaks: $d \cdot \sin\theta = m\lambda$.

Distance between nearest principal peaks on the viewing screen:

$$s = \frac{y_m}{m} = \frac{L \cdot \tan\theta_m}{m.} \approx \frac{L \cdot \sin\theta_m}{m.}$$

$$s = \frac{L \cdot \lambda}{d} \propto \frac{1}{d}.$$



when slit separation is increased by a factor of 3:

$d' = 3d$. $s' = \frac{1}{3} d$.

Then, the distance between principal peaks on screen is reduced by a factor of 3 .

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13 . For N-slit interference, the number of secondary maxima between principal max is: $N-2$.

Now: $N-2 = 2$. $\Rightarrow$ $N = 4$.

i.e. 4 slits are illuminated .

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14. $\lambda = 0.566\ \mu m$. $W = 24.7\ \mu m$.

First minimum of single slit pattern: $y = 5 \times 1.45 = 7.25$ cm .

$W \cdot \sin\theta = \lambda$.

$$L = \frac{y}{\tan\theta} = \frac{y}{\tan\left(\sin^{-1}\frac{\lambda}{W}\right)} = 3.16\ m .$$