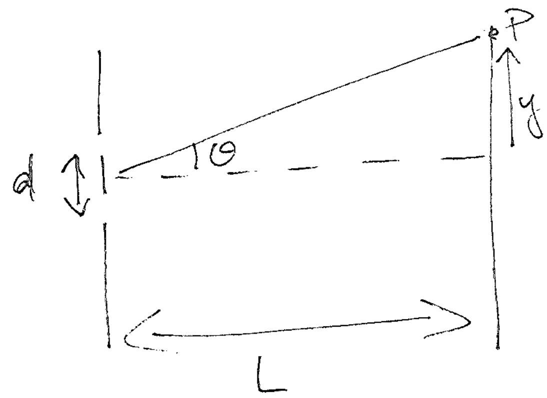
Physics 152, HW#9

Mastering Physics: 9 problems from Chapter 17

Two written problems

17.13



$d = 0.5\text{mm} = 0.5\times10^{-3}\text{m} = 5\times10^{-4}\text{m}$

$y = 2\text{cm} = 0.02\text{m}$

$L = 1.5\text{m}$

at P, 6th bright spot.

a.) WHAT is Extra distance, Δr?

We Know that at bright spots, $\Delta r = m\lambda$ but that doesn't help us since we weren't given λ.

For screen very far away (which is true here), we also know that $\Delta r = d\sin\theta$

Since $y = L\tan\theta$ We can solve for θ then ~~for~~ Δr.

$y = L\tan\theta \Rightarrow 0.02\text{m} = 1.5\text{m}\tan\theta \Rightarrow \tan\theta = \frac{0.02\text{m}}{1.5\text{m}} = 0.01333 \Rightarrow \theta = \tan^{-1}(0.01333)$

$\therefore \theta = 0.764°$

$\Delta r = d\sin\theta = 5\times10^{-4}\text{m}\sin(0.764°) = 6.67\times10^{-6}\text{m} \times \frac{1\text{nm}}{10^{-9}\text{m}} = \underline{6670\text{nm}}$

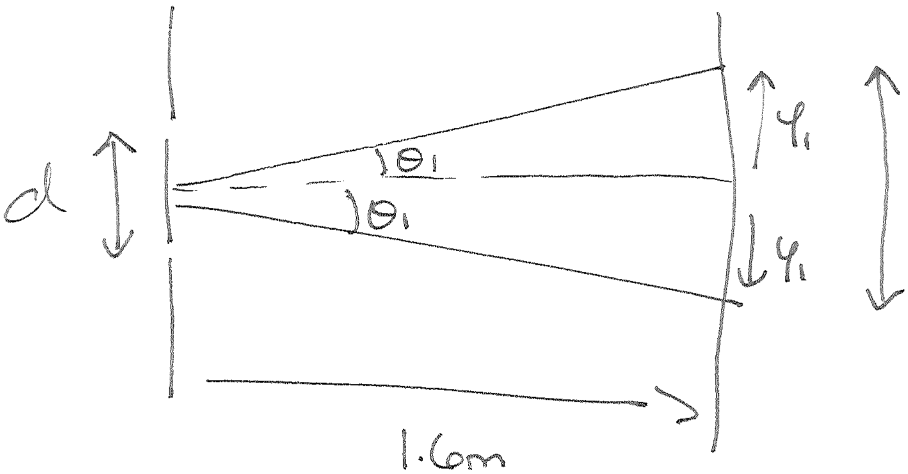
b.) what is wavelength?

Now we can use $\Delta r = m\lambda$! $\lambda = \frac{\Delta r}{m} = \frac{6670\text{nm}}{6} = \underline{1110\text{nm}}$

6th bright spot

17.40

$d = 0.36\,mm = 0.36(1\times10^{-3})m$
$= 3.6\times10^{-4}m$



$5.5\,mm = 5.5\times10^{-3}\,m$

what is wavelength?

MAXIMA at $d\sin\theta = m\lambda \Rightarrow d\sin\theta_1 = (1)\lambda \Rightarrow \lambda = d\sin\theta_1$

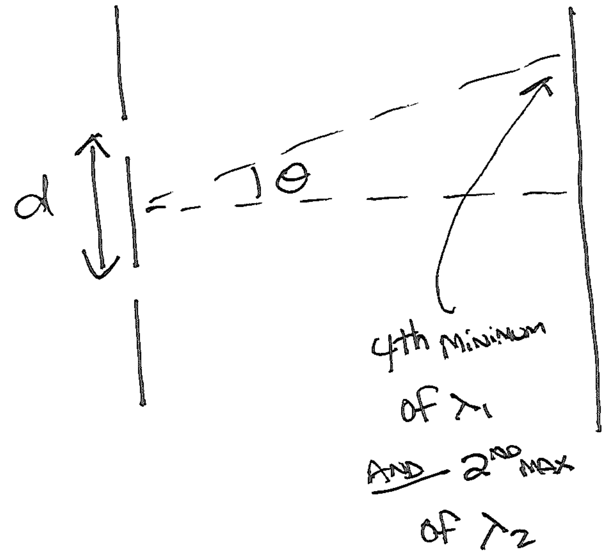
FIND θ_1 FROM $y_1 = L\tan\theta_1$ $\quad y_1 = \dfrac{5.5\times10^{-3}m}{2} = 2.75\times10^{-3}m$

$\therefore \tan\theta_1 = \dfrac{y_1}{L} = \dfrac{2.75\times10^{-3}m}{1.6\,m} = 1.72\times10^{-3} \Rightarrow \theta_1 = \tan^{-1}(1.72\times10^{-3})$
$= 0.098^\circ$

$\therefore \lambda = d\sin\theta_1 = (3.6\times10^{-4}m)\sin 0.098^\circ = 6.187\times10^{-7}m$

$6.187\times10^{-7}m \times \dfrac{1\,nm}{1\times10^{-9}m} = 618.7\,nm = 620\,nm$

Double Slit #2



$d = 0.35\,mm = 0.35 \times 10^{-3}\,m = 3.5 \times 10^{-4}\,m$

$\lambda_1 = \frac{d}{8} = \frac{3.5 \times 10^{-4}\,m}{8} = 4.375 \times 10^{-5}\,m$

WHAT λ_2 SO THAT 4th MINIMUM OF FIRST LASER AS AT 2ND MAXIMUM OF 2ND LASER

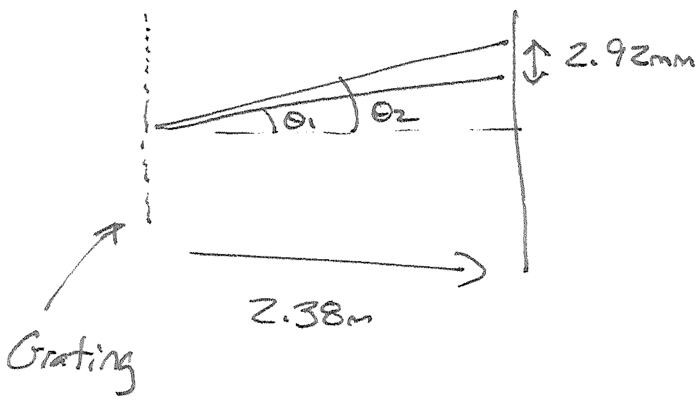
SO AT THE SAME θ: $d \sin\theta = 2\lambda_2$ AND $d \sin\theta = (3 + \frac{1}{2})\lambda_1$

FIRST MINIMA IS AT $m = 0$ ⇒ $m = 3$ IS 4th MINIMA

$\therefore\ 2\lambda_2 = 3.5\lambda_1 \Rightarrow \lambda_2 = \left(\frac{3.5}{2}\right)\lambda_1 = \left(\frac{3.5}{2}\right) 4.375 \times 10^{-5}\,m$

$\Rightarrow \lambda_2 = 7.66 \times 10^{-5}\,m \times \frac{1000\,mm}{m} = \underline{0.0766\,mm}$

DIFFRACTION GRATING



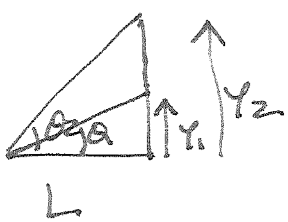
GRATING WITH 900 slits per Centimeter

$$\Rightarrow d = \frac{1cm}{900} = \frac{0.01m}{900} = 1.11\times10^{-5}m$$

First ORDER Bright Spots $\Rightarrow d\sin\theta_1 = (1)\lambda_1$

$$d\sin\theta_2 = (1)\lambda_2$$

$$\therefore \lambda_2 - \lambda_1 = d\sin\theta_2 - d\sin\theta_1 = d(\sin\theta_2 - \sin\theta_1)$$



$$y_1 = L\tan\theta_1$$

$$y_2 = L\tan\theta_2$$

$$\Rightarrow y_2 - y_1 = L(\tan\theta_2 - \tan\theta_1) \Rightarrow \tan\theta_2 - \tan\theta_1 = \frac{y_2 - y_1}{L} = \frac{2.92\times10^{-3}m}{2.38m}$$

$$\Rightarrow \tan\theta_2 - \tan\theta_1 = 0.00122$$

SO IF WE ASSUME THE ANGLES ARE SMALL, We say $\tan\theta_2 - \tan\theta_1$ is very close to $\sin\theta_2 - \sin\theta_1$

$\sin\theta_2 - \sin\theta_1 = 0.00122$ AND $\lambda_2 - \lambda_1 = d(\sin\theta_2 - \sin\theta_1)$

$\Rightarrow \lambda_2 - \lambda_1 = (1.11 \times 10^{-5}\,m)(0.00122) = 1.36 \times 10^{-8}\,m$

YOU'RE SUPPOSED to be impressed by How close the two WAVELENGTHS ARE.

17.54 Melanin on Beetles spaced $2\mu m$ Apart

$\Rightarrow d = 2\mu m = 2\times10^{-6} m$

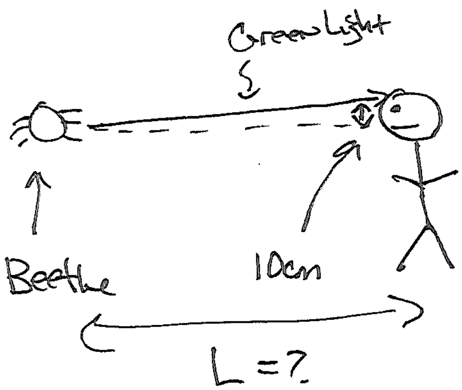
$\theta_1 = ?$ for $\lambda = 550 nm = 550(1\times10^{-9})m = 5.5\times10^{-7} m$

$d\sin\theta = m\lambda \Rightarrow \sin\theta_1 = \frac{(1)\lambda}{d} = \frac{5.5\times10^{-7} m}{2\times10^{-6} m} = 0.275$

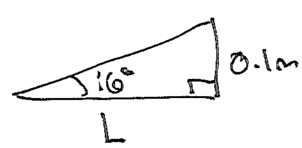
$\therefore \theta_1 = \sin^{-1}(0.275) = 15.962° = 16°$

b.) IF VERTICAL distance BETWEEN Beetle AND eyes is 10cm, How far AWAY should you STAND?

$10cm = 0.1m$



$\Rightarrow$



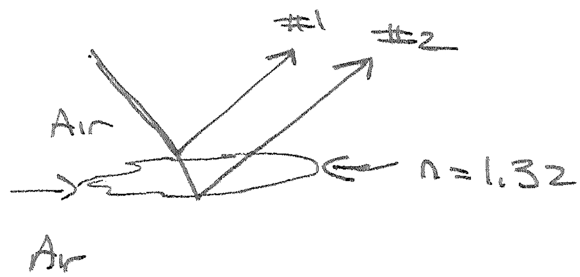
$\tan 16° = \frac{0.1m}{L}$

$\Rightarrow L = \frac{0.1m}{\tan 16°} = 0.349m$

$= 0.4m$

Interference from soap Film

Basically we have This



#1 Has a Reflective phase shift since ~~its~~

~~Bouncing off~~
~~Back for Air and of 1.32 surface~~

Surface below has larger index of Refraction

#2 Does not because when it Reflected, Surface below

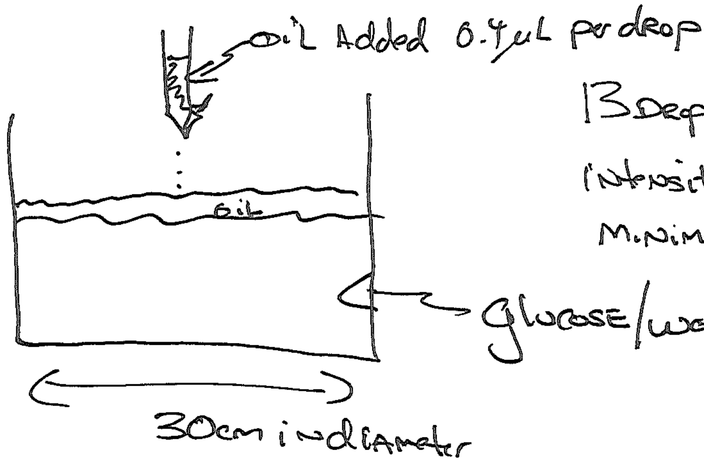
was Air ($n=1$) so had lower index.

Thin Film Interference with one phase change $\Rightarrow$

$2t = \frac{m\lambda}{n}$ for destructive.

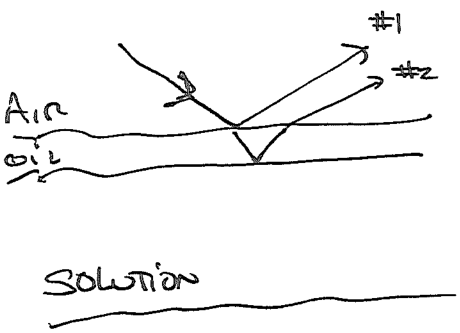
$\therefore \quad t = \frac{m\lambda}{2n} = \frac{(1)(540\,nm)}{2(1.32)} = 205\,nm$

17.60



13 drops of oil ADDED to make intensity of 600nm light A MINIMUM.

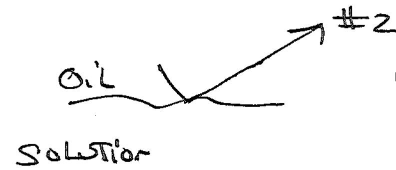
a) # of phase shifts



Phase shifts OCCUR when Material Below has A LARGER INDEX

Air has index of 1, the smallest possible
$\Rightarrow$ Must have phase shift ON #1.

For #2



we're told oil's index is smaller
$\Rightarrow$ Solution's is LARGER
$\Rightarrow$ Also phase shift on #2

$\Rightarrow$ Two phase shifts IN TOTAL

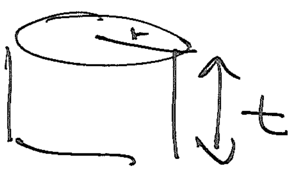
b.)
$\Rightarrow$ BACK TO THE "NORMAL" CONDITIONS THAT Destructive INTERFERENCE OCCURS when $2t = (m + 1/2)\frac{\lambda_0}{n_{oil}}$

c) FIRST MINIMUM OCCURS when $m=0$ $\Rightarrow 2t = (0+\tfrac{1}{2})\dfrac{\lambda}{n_{oil}}$

$$\Rightarrow 2t = \frac{0.5\lambda}{n_{oil}} \quad \Rightarrow n_{oil} = \frac{0.5\lambda}{2t}$$

$$\lambda = 600nm = 600(10^{-9})m = 6\times10^{-7}m$$

To find THICKNESS, USE the fact the Oil is filling THE Dish AND is therefore cylindrical in shape



Volume of cylinder, $V = \pi r^2 t$

$r = 15cm = 0.15m$ (Diameter was 30cm)

13 drops of oil, EACH $0.4\mu L$ $\Rightarrow V = 13(0.4)\times10^{-6}L = 5.2\times10^{-6}L$

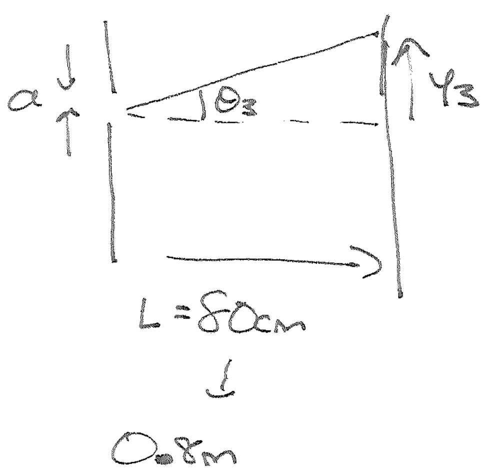
$1000L = 1m^3$ (I ACTUALLY had to use Google to remember this!)

$$\Rightarrow V = 5.2\times10^{-6}L \times \frac{1m^3}{1000L} = 5.2\times10^{-9}\,m^3$$

$$\therefore t = \frac{V}{\pi r^2} = \frac{5.2\times10^{-9}\,m^3}{\pi(0.15m)^2} = 7.356\times10^{-8}m$$

$$\text{So } n_{oil} = \frac{0.5(6\times10^{-7}m)}{2(7.356\times10^{-8}m)} = 2.039 = \underline{\underline{2.0}}$$

Single Slit



$\lambda = 633nm = 633(1\times10^{-9}m) = 6.33\times10^{-7}m$

Diffence Between $p=+3$ AND $p=-3$

MINIMA is 17.9mm

$\Rightarrow$ Distance from center

$y_3 = \frac{17.9mm}{2} = 8.95mm = 8.95\times10^{-3}m$

$\tan\theta_3 = \frac{y_3}{L} = \frac{8.95\times10^{-3}m}{0.8m} = 0.011188 \Rightarrow \theta_3 = \tan^{-1}(0.011188) = 0.64°$

Singslit MINIMA: $a\sin\theta_p = p\lambda$

$a\sin\theta_3 = 3\lambda \Rightarrow a\sin 0.64° = 3(6.33\times10^{-7}m)$

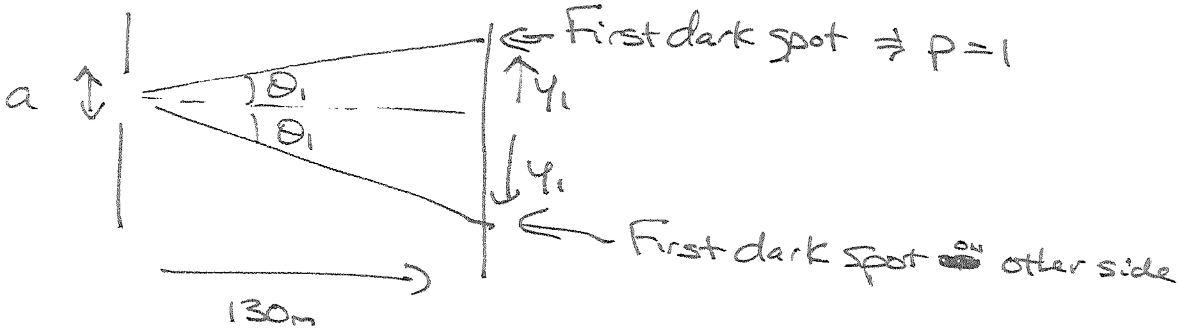
$\Rightarrow a = \frac{3(6.33\times10^{-7}m)}{\sin .64°} = 0.0001697m \cdot \frac{1\mu m}{1\times10^{-6}m} = 169.7\mu m$

$= 170\mu m$

b) if in water? λ would get smaller so each θ would get smaller ($a\sin\theta = p\lambda$) $\therefore$ Everything would get closer together so central peak would decrease.

17.65 $\rightarrow$ 30cm-wide CRACK Acts as Single Slit

$f = 31\,kHz = 31000\,Hz$



TOTAL WIDTH is $2y_1$

$a\sin\theta_p = p\lambda \Rightarrow a\sin\theta_1 = (1)\lambda$

$a = 30cm = 0.3m$, for any wave $\lambda f = V \Rightarrow \lambda f = V_{sound}$

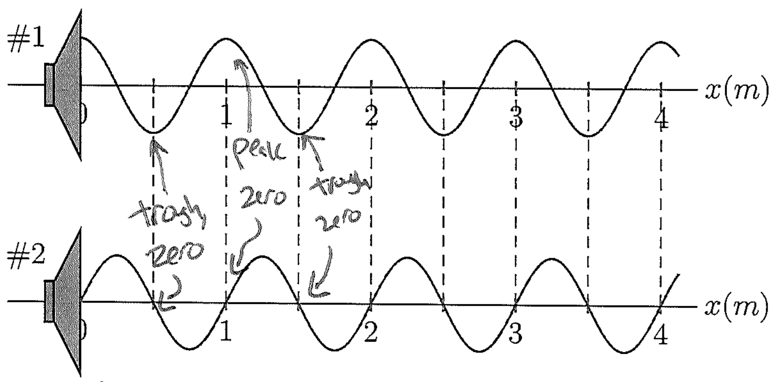
$\Rightarrow \lambda = \frac{V_{sound}}{f} = \frac{340m/s}{31000Hz} = 0.01097m$

$\therefore \sin\theta_1 = \frac{0.01097m}{0.3} = 0.03657 \Rightarrow \theta_1 = \sin^{-1}(0.03657) = 2.096°$

$y_1 = L\tan\theta_1 = (130m)\tan 2.096° = 4.757m$

So width $= 2(4.757m) = 9.5137m = 9.5m$

Written Question #1 The figure shows a graph of two speakers emitting a sound wave (at time $t = 0$). The speakers emit waves of equal wavelength, but the wave from speaker #2 starts at zero while #1's wave starts at its peak value. The second speaker is drawn below the first, so that the figure is clearer, but you should think of the two speakers on the same line with their waves overlapping.

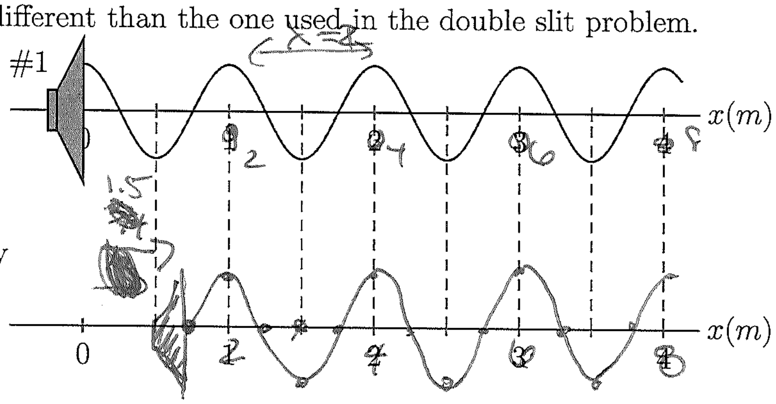


a.) These graphs are neither completely the same nor or they completely opposite to each other ⇒ Neither total constructive or destructive

(a.) Explain why the interference of these two waves will be neither completely constructive nor completely destructive. Your explanation should be based on the figure and not on any equation.

(b.) On the axes provided below, redraw the figure with speaker #2 moved to the right so that the two waves have total constructive and then total destructive interference. For full points, you must explain your choices.

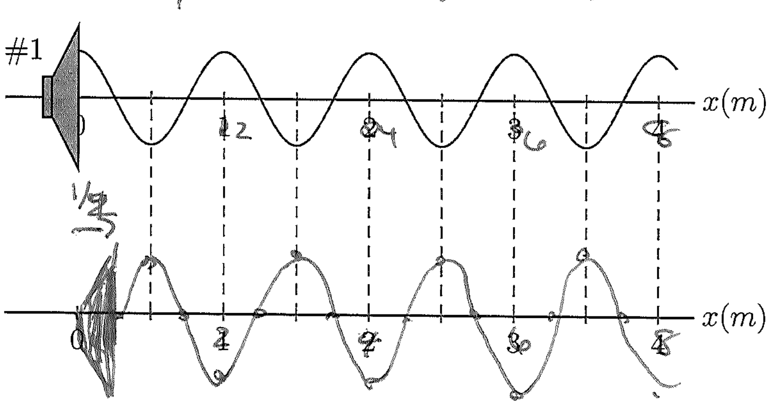
(c.) In each case, what fraction of the wavelength, $\Delta x/\lambda$, did #2 need to be moved? Explain why this condition is different than the one used in the double slit problem.



#2 positioned to constructively interfere

Shift speaker until graphs are identical

$$\frac{\Delta x}{\lambda} = \frac{1.5\text{m}}{2\text{m}} = 3/4$$



#2 positioned to destructively interfere

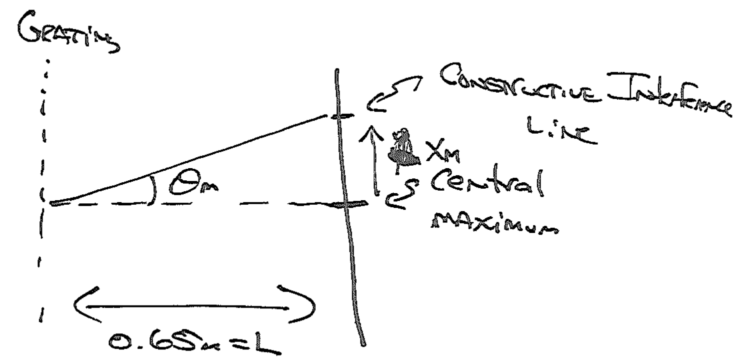
Shift speaker until graphs are completely opposite

$$\frac{\Delta x}{\lambda} = \frac{½\text{m}}{2\text{m}} = ¼$$

Conditions are different because the waves are not exactly identical to begin with. We only needed to shift by ¼ to make them opposite because they were already ½ different. (Notice that ¾ − ¼ = ½ just like 1 − ½ = ½)

Written Question #2: Laser with $\lambda = 670nm$, Diffraction grating with 500 lines/mm. Sketch pattern on screen 0.65m.

1st Start with sideways view:



Everywhere else is Dark! ⇒ Series of lines.

Lines appear where $d\sin\theta_m = m\lambda$ and at a height $x_m = L\tan\theta_m$.

Note: When we turn the picture back so we are looking at the lines vertically, it will make more sense that we are calling the height "x_m".

500 lines per mm ⇒ In one mm there are 500 lines ⇒ $d = \frac{1}{500}mm$

$$\Rightarrow d = \frac{1}{500}mm \times \frac{m}{1000mm} = 2\times10^{-6}m$$

$$\lambda = 670nm = 670(10^{-9}m) = 6.7\times10^{-7}m$$

$M = 0 \Rightarrow d\sin\theta_0 = 0 \Rightarrow \theta_0 = 0^\circ \Rightarrow X_0 = 0 \Rightarrow$ Central MAXIMUM ALREADY ON FIGURE.

$m = 1 \Rightarrow d\sin\theta_1 = (1)\lambda \Rightarrow \sin\theta_1 = \frac{\lambda}{d} = \frac{6.7\times10^{-7}m}{2\times10^{-6}m} = 0.335$

$\therefore\ \theta_1 = \sin^{-1}(0.335) = 19.57^\circ,\ X_1 = L\tan\theta_1 = 0.65m\tan(19.57^\circ) \Rightarrow$

$X_1 = 0.2311m = 23cm$

$M = -1 \Rightarrow d\sin\theta_{-1} = -\lambda \Rightarrow \theta_{-1} = \sin^{-1}(-0.335) = -19.57^\circ \Rightarrow X_{-1} = -23cm$

$M = 2 \Rightarrow d\sin\theta_2 = (2)\lambda \Rightarrow \sin\theta_2 = \frac{2\lambda}{d} = \frac{2(6.7\times10^{-7}m)}{2\times10^{-6}m} = 0.67$

$\therefore\ \theta_2 = \sin^{-1}(0.67) = 42.067^\circ \Rightarrow X_2 = 0.65m\tan(42.067^\circ) =$

$0.5866m = 59cm$

$M = -2$ gives $\theta_{-2} = -42.067^\circ$ AND $X_{-2} = -59cm$

$m = 3 \Rightarrow d\sin\theta_3 = (3)\lambda \Rightarrow \sin\theta_3 = \frac{3\lambda}{d} = \frac{3(6.7\times10^{-7}m)}{2\times10^{-6}m} = 1.005$

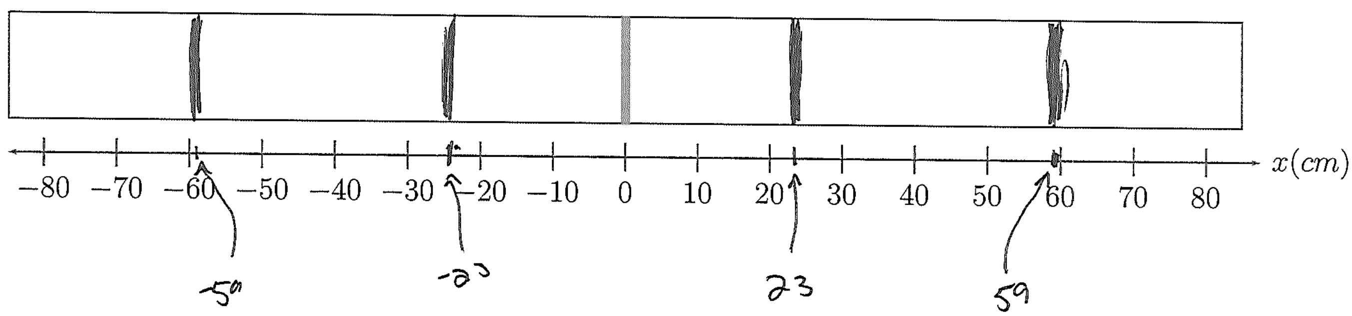
THERE IS NO ANGLE FOR which $\sin\theta > 1 \Rightarrow$ NO MORE LINES EXIST.

SO THERE IS A TOTAL OF 5 LINES, SEE NEXT PAGE FOR SKETCH.

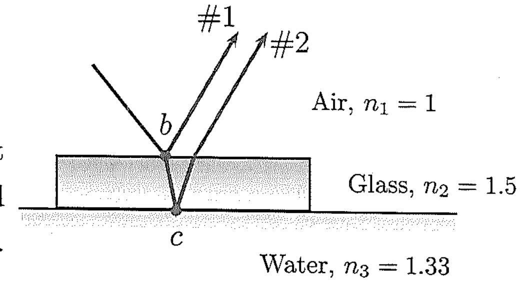
Written Question: A laser beam of wavelength 670 nm shines through a diffraction grating that has 500 lines/mm.

(a.) How many lines in total would appear on viewing screen which is is 0.65 m behind the grating? For full points, you must explain your answer and show any necessary calculations.

(b.) The figure below shows the central maximum. (From the vantage of the figure, the diffraction grating's slits are vertical.) Sketch the interference pattern, using the scale provided!, that appears on the screen that is 0.65 m behind the grating. Any calculations not shown in part (a.) must be shows here for full points.

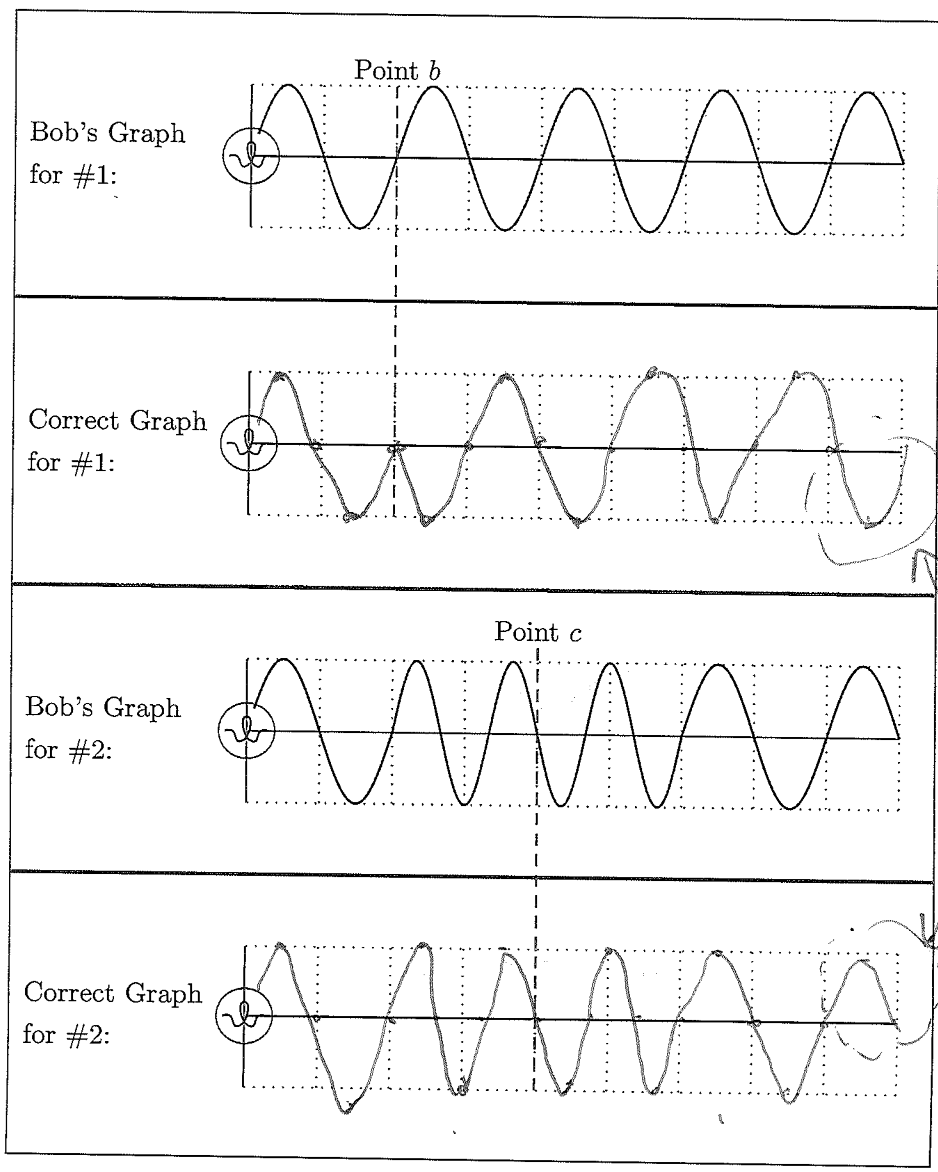


Written Question #3: On an exam, Bob-the-physics-student is asked to draw the electric field graphs for the two reflected beams of light, #1 and #2, for a glass film floating on water.



(a.) Bob has not been paying attention in class, so he made just one mistake on his graphs. Explain what Bob did wrong and draw the correct graphs on the axes below his attempts. (Bob has been asked to draw the two graphs as if the beams were propagating in straight lines so as to make figures similar to the ones in lecture. Point b is where #1 reflects off the top surface. Point c is where #2 reflects off the bottom surface. The shaded region is where #2 is inside the film.)

(b.) When combined, do the two reflected waves interfere constructively, destructively, or somewhere in between? Your explanation should be based on the graph, not on any equation. (Use the correct graphs and *not* Bob's to answer this question.)



Bob Forgot the Reflective phase shifts. They Occur when the index of the material Below is Larger than the one above ⇒ There will be one at b but not c.

Completely Backwards to each other ⇒ will have total destructive interference when they mix.