PY106 Fall 2022 Quiz 5

Yang Jeong Yong

TOTAL POINTS

18 / 20

QUESTION 1

Problem 1 5 pts

1.1 1a **1 / 1**

✓ **+ 1 pts** **Correct answer: In Phase. The perpendicular bisector goes through the middle of the two sources. Anywhere along that line is constructive interference and path length equal to zero. Peak from one source meets a peak from the other source.**

+ **0 pts** Any other answer

1.2 1b **1 / 1**

✓ **+ 1 pts** **Correct: Counting clockwise from perpendicular bisector (where m=0, $\Delta L=0\lambda$). When we get to the right 3 o'clock, we are at m=4, so $\Delta L=4\lambda$**

+ **0 pts** Any other answer

1.3 1c **1 / 1**

✓ **+ 1 pts** **Counting clockwise from perpendicular bisector (where m=0, $\Delta L=0\lambda$). When we get to the black dot, we are at m=2, so $\Delta L=2\lambda$**

+ **0 pts** Any other answer

1.4 1d **2 / 2**

✓ **+ 2 pts** **Correct: Note: The correct answer is 440 Hz. This comes from using $$f = \frac{v}{\lambda}$$ with $$\Delta L = m \lambda$$ or $$\lambda = \frac{\Delta L}{m}$$ $$f = \frac{mv}{\Delta L}$$ where m=2 (from picture), ΔL = 3.4 m – 1.9 m = 1.5 m and v=330 m/s (which was given)**
$$f = \frac{2 \times 330 m/s}{1.5 m} = 440 Hz$$

+ **2 pts** If you got 1c incorrect, found a different path length difference other than 2 times wavelength, but your work was consistent with the rest of the above

+ **1 pts** $$f = \frac{v}{\lambda}$$ but did not have work consistent with 1c (even if 1c was incorrect) or did not take into account the actual lengths given

+ **0 pts** Click here to replace this description.

QUESTION 2

Problem 2 4 pts

2.1 2a **2 / 2**

✓ **+ 2 pts** **Correct: $$d\sin\theta=m\lambda$$**

Small angle approximation: $$\sin\theta=\tan\theta = x/L$$.

Our equation now becomes $$d x/L = m\lambda$$.

Look at the picture, we can choose any m and associated x. For example: m=1 maxima occurs at x = 2cm = 0.02 m.

Solve for $$d = m \lambda L / x =$$ (1)(500 nm)(2.2 m) / (0.02 m) = 55,000 nm

+ **1.75 pts** Everything correct, except did not convert cm to m so the units worked out, a minor math error or inconsistency between m and distance, leading to incorrect result

+ **1 pts** Showed some work, used correct equations and identified main features of interference pattern but did not solve correctly.

+ **0 pts** Insufficient work

2.2 2b **2 / 2**

✓ **+ 2 pts** **Correct: $$a\sin\theta=m\lambda$$.**

Small angle approximation: $$\sin\theta=\tan\theta = x/L$$.

Our equation now becomes $$a x/L = m\lambda$$. The first minima, m=1, occurs at 10 cm = 0.1 m.

Solve for $$a = m \lambda L / x =$$ (1)(500 nm)(2.2 m) / (0.1 m) = 11,000 nm

Or m of double slit at m=5 is missing (shown at 10 cm), therefore d/a = 5 or a = d/5 = (55,000 nm)/5 = 11,000 nm

+ **2 pts** a=d/5 consistent with part (a) even if answer is incorrect.
+ **1.75 pts** Minor math error or units error
+ **1 pts** Wrote correct equation AND identified important points from the pattern and started toward a solution
+ **0 pts** Insufficient work

QUESTION 3

Problem 3 4 pts

3.1 3a 2 / 2

✓ + **2 pts** **Correct: Fully correct solution that follows the 5 step method: $$\Delta_t=0$$ (no phase shift since $$n_\mathrm{glass}>n_\mathrm{film}$$), $$\Delta_b=2t+\lambda_\mathrm{film}/2$$ (there is a phase shift because $$n_\mathrm{film}<n_\mathrm{glass}$$).**

Path length difference: $$\Delta=\Delta_b-\Delta_t=2t+\lambda_\mathrm{film}/2$$

Set the path length difference to $$m\lambda_\mathrm{film}$$ for constructive interference: $$2t+\lambda_\mathrm{film}/2 = m\lambda_\mathrm{film}$$

Solve for t: $$t = 1/2 \lambda_\mathrm{film} (m-1/2)$$

$$m=1$$ will yield minimum thickness, thus $$t=1/4 λ_\mathrm{film}$$

$$\lambda_\mathrm{film}=\lambda_\mathrm{air}/n_\mathrm{film}=440 \ \mathrm{nm} / 1.25 = 352 \ \mathrm{nm}$$.

$$t_\mathrm{min}=1/4 (352 \ \mathrm{nm}) = 88 \ \mathrm{nm}$$.

+ **1.5 pts** Correct approach, but small errors, such as setting incorrect interference condition or math error
+ **0.5 pts** Showed some work, but did not arrive at correct approach
+ **0 pts** Insufficient work shown

3.2 3b 1.5 / 2

+ **2 pts** Correct: The index of refraction of the film is higher than the air around it, ($$n_{film} > n_{air}$$) so the wave reflecting off of the **top** of the film will have a phase shift, while the wave reflecting from the bottom of the film will not.

$$\Delta_t=\lambda_\mathrm{film}/2$$

$$\Delta_b=2t$$

Path length difference: $$\Delta=\Delta_b-\Delta_t=2t-\lambda_\mathrm{film}/2$$

Set the path length difference to $$m\lambda_\mathrm{film}$$ for constructive interference: $$2t-\lambda_\mathrm{film}/2 = m\lambda_\mathrm{film}$$

Solve for $$\lambda_{film} = 2t/(m+1/2)$$

The integer value which will create the longest wavelength for the reflected light is $$m = 0$$. Thus, $$\lambda_{film} = 4t =4 (120 \ \mathrm{nm}) = 480 \ \mathrm{nm}$$.

To get $$\lambda_{air}$$ we need to convert using the index of refraction for the film: $\lambda_{air} = (\lambda_{film}) (n_{film}) = (480 \ \mathrm{nm}) (1.30) = 648 \ \mathrm{nm}$

✓ **+ 1.5 pts** Correct approach, but small errors, such as setting incorrect interference condition or math error

+ 0.5 pts Showed some work, but did not arrive at correct approach

+ 0 pts Insufficient work

QUESTION 4

Problem 4 7 pts

4.1 4a 1 / 1

✓ **+ 1 pts** Correct: 8.0 eV

+ 0.5 pts Expressed answer in J by converting 1eV to 1.6E-19 J or otherwise confused eV and J.

+ 0 pts Incorrect

4.2 4b 0 / 1

+ 1 pts Correct is between 0 and 1000, inclusive. From (a), light of frequency f (meaning $E=hf$) causes electrons to be emitted with various K (which can be $K=0$ to $K=K_{max}$). For each photon with energy $E=hf$, an electron _can_ certainly be emitted, provided the energy is greater than the work function of the metal plate. Some, though, may need an energy larger than the work function to emit them. The point is that it's possible to get zero and possible to get 1000, and also everything in between. You certainly cannot get more than 1000.

✓ **+ 0 pts** Incorrect

4.3 4c 2 / 2

✓ **+ 2 pts** Correct: Initially the light shining on the plate is of frequency $hf=Kmax1+W_0$ with $Kmax1$ being the result you found in part (a): $Kmax1 = 8.0 \ \mathrm{eV}$

Then the frequency of the light is doubled $2hf=Kmax2+W_0$ with $Kmax2=e\Delta V_s=18.0 \ \mathrm{eV}$.

From these two equations we can solve to find hf since the work function will be the same in both cases, $hf=Kmax2-Kmax1=18.0 \ \mathrm{eV} -8 \ \mathrm{eV}=10.0 \ \mathrm{eV}$

With our value of hf we can solve for our work function: $W_0=hf-Kmax1=10.0 \ \mathrm{eV} -8 \ \mathrm{eV}=2.0 \ \mathrm{eV}$.

+ 1 pts Made a reasonable attempt at solving for the work function

+ 0 pts Insufficient work

4.4 4d 2 / 2

✓ **+ 2 pts** Correct: $v = \sqrt{2K/ m}$ = sqrt [(2 *8.0 eV * 1.6e-19 J)/9.1e-31 kg] = 1.677e-6 m/s.

$\lambda = h/mv$ = 6.63e-34 J / [(9.1e-31 kg)(1.677e-6 m/s)]=4.344e-10 nm = 0.43 nm

Note that I mistakenly put round to nearest whole nanometer because I was off by a factor if 10^2. So, everyone got this correct.... Happy holidays!

4.5 4e 0.5 / 1

+ 1 pts Correct: radio

✓ **+ 0.5 pts** Any other answer... gamma rays in an MRI machine? Ouch! X-rays? Don't we use them for something else? UV: ouch, we will get skin cancer... microwaves? we'll all get nice and warm!

gradescope

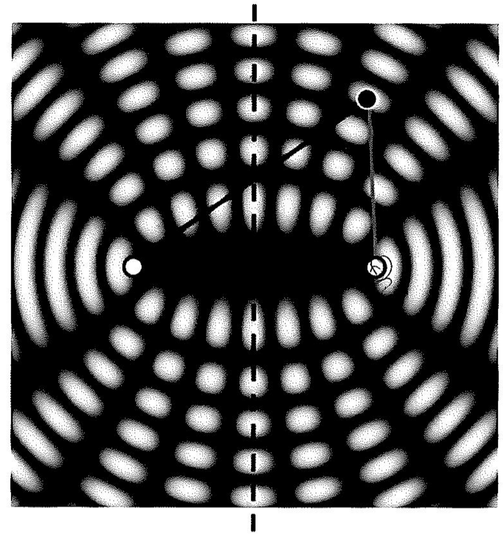
PY106 Quiz 5 December 15, 2022

NAME: Jeongyong Yang ID NUMBER: U95912941

You must show work to earn partial credit for all questions that are not multiple choice.

PROBLEM 1 – 5 points

Two speakers, whose locations are indicated by the white dots, produce sound waves at the same frequency and amplitude. The diagram is of a moment in time and shows the interference pattern of these waves, such that black regions have zero displacement, and white regions have large displacement. The dashed line overlayed on the figure is the perpendicular bisector. The black dot (toward the upper right) is some distance away from the right speaker and some distance away from the left speaker.



[1 point] (a) The two sources are…

[✓] In phase [ ] 180 degrees out of phase [ ] We cannot tell

[1 point] (b) How far apart are the speakers in terms of wavelength?

[ ] 0 [ ] 0.5 [ ] 1.0 [ ] 1.5 [ ] 2.0 [ ] 2.5 [ ] 3.0 [ ] 3.5 [✓] 4.0 [ ] 4.5 [ ] 5.0

[1 point] (c) Consider the location indicated by the black dot. What is the difference in distance from each speaker to that location in terms of wavelength?

[ ] 0 [ ] 0.5 [ ] 1.0 [ ] 1.5 [✓] 2.0 [ ] 2.5 [ ] 3.0 [ ] 3.5 [ ] 4.0 [ ] 4.5 [ ] 5.0

[2 points] (d) Continuing from (c), the black dot in the diagram is 3.4 m and 1.9 m from the left and right speakers, respectively. Taking the speed of sound in air at $v = 330$ m/s, determine the frequency of sound the speakers are producing.

$|d_1 - d_2| = n\lambda$

$1.5 = 2\lambda$

$\lambda = 0.75\text{m}$

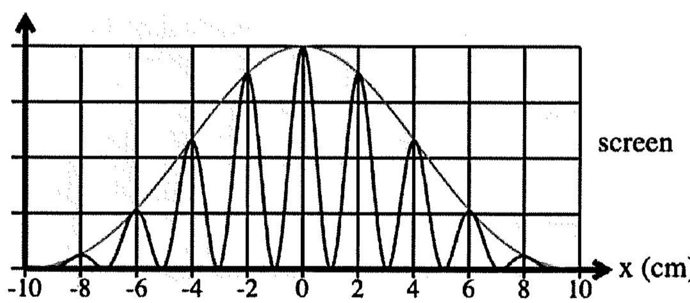
$v = f\lambda$

$f = \frac{v}{\lambda} = \frac{330}{0.75} = 440$

440 Hz

PROBLEM 2 – 4 points

Light from a green laser, with a wavelength of 500 nm, shines on a double slit. The picture shows the intensity of the light as a function of position on a screen 2.20 m from the double slit. The center of the pattern corresponds to x = 0 cm.



[2 points] (a) Determine d, the distance between the two slits in the double slit. $x=2$, first maxima

$\tan\theta = \frac{x}{L} = \frac{0.02}{2.2}$ $\theta = 0.521$

$\theta = \tan^{-1}\left(\frac{0.02}{2.2}\right)$

$d\sin\theta = m\lambda$

$d = \frac{m\lambda}{\sin\theta} = \frac{1 \cdot 500\text{nm}}{\sin(0.521)}$

$= 55002 \approx 55000$

d = 55000 nm

[2 points] (b) Determine a, the width of each of the two slits in the double slit.

$x=1$, first minima

$\tan\theta = \frac{x}{L} = \frac{0.01}{2.2}$

$\theta = \tan^{-1}\left(\frac{0.01}{2.2}\right) = 0.26$

$d\sin\theta = m\lambda$

$a = \frac{m\lambda}{\sin\theta} = \frac{(1)(500)}{\sin(0.26)} = 11061 \approx 11000$

a = 11000 nm

PROBLEM 3 – 4 points

[2 points] (a) In a thin-film scenario, there is a film of liquid ($n = 1.25$) sandwiched between two pieces of glass ($n = 1.50$). From above, you shine blue laser light of wavelength of 440 nm (in air) straight down. Determine the minimum non-zero thickness of the film of liquid needed to produce completely constructive interference for the reflected light.

① $n_1 > n_2$ ④ constructive

Answer: 80 nm

↓ — glass ($n = 1.5$) n_1 $\Delta t = 0$ $2t + \lambda_{film}/2 = m\lambda_{film}$

— liquid ($n = 1.25$) n_2 ② $n_3 > n_2$ $\Delta b = 2t + \lambda_{film}/2$ $2t = (m - \frac{1}{2})\lambda_{film}$ $m = 1 \to$ minimum

— glass ($n = 1.5$) n_3 ③ $\Delta L = 2t + \lambda_{film}/2$ ⑤ $2t = (m - \frac{1}{2})\frac{\lambda_{vacuum}}{n_{film}}$ $\to t = \frac{(1-\frac{1}{2})(400)}{2(1.25)} = \frac{400}{4 \cdot 1.25} = 80$

[2 points] (b) In a different scenario, you have a thin film of soapy water ($n = 1.35$) with a uniform thickness of 120 nm. There is air ($n = 1.00$) on both sides of the film. Determine the longest wavelength (in air) for which reflected light experiences completely constructive interference.

Answer: 216 nm

— air ($n = 1.00$) ① $n_2 > n_1$ ④ constructive

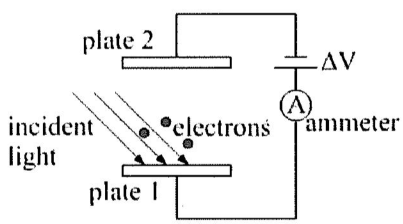
— soapy ($n = 1.35$) $\Delta t = \lambda/2$ $2t - \lambda/2 = m\lambda_{film}$ $\lambda_{vacuum} = \frac{2t \cdot n_{film}}{m + \frac{1}{2}}$

— air ($n = 1.00$) ② $n_2 > n_3$ $2t = (m + \frac{1}{2})\lambda_{film}$

$\Delta b = 2t$ ⑤ $2t = (m + \frac{1}{2})\frac{\lambda_{vacuum}}{n_{film}}$

③ $\Delta L = 2t - \lambda/2$ $= \frac{2(120)(1.35)}{1 + \frac{1}{2}} = 216$

PROBLEM 4 – 6 points



[1 point] (a) Light of frequency f shines on metal plate 1, as shown, causing electrons to be emitted. The stopping potential, ΔV_s, is found to be 8.0 V. Determine the maximum kinetic energy of the emitted electrons.

max $KE = e\Delta V = 8$ eV

Answer: 8 eV

[1 point] (b) The battery voltage is now set to 0 V. If 1,000 photons with frequency f are incident on plate 1, how many electrons will be emitted? [ ] Zero [ ] Between 0 and 1,000, inclusive [✓] Exactly 1,000

[2 points] (c) The frequency of light shining on metal plate 1 is now doubled to $2f$. The battery is adjusted and ΔV_s is found to be 18.0 V. Find the work function of this metal. *Hint: you will need your result from part (a).*

① $hf = k_{max} + W_0$ ② $W_0 = 2hf - 18\text{eV} \to f = (W + 18)/2h$

$hf = 8\text{eV} + W_0$

$W_0 = hf - 8\text{eV}$ $h = 6.63 \times 10^{-34}\,\text{J}\left(\frac{1\text{eV}}{1.6 \times 10^{-19}\,\text{J}}\right) = 4.144 \times 10^{-15}\,\text{eV}$ $\frac{W + 8}{h} = \frac{W + 18}{2h}$ $2W + 16 = W + 18$

$f = \frac{W + 8\text{eV}}{h}$ $W = 2$

Answer: 2 eV

[2 points] (d) Returning to part (a) where $\Delta V_s = 8.0\ V$, calculate the de Broglie wavelength associated with the fastest emitted electrons. Round your answer to the nearest whole nanometer.

$8\text{eV}\left(\frac{1.6 \times 10^{-19}\,\text{J}}{1\text{eV}}\right) = 1.28 \times 10^{-18}\,\text{J} = \frac{1}{2}mv^2$ $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31}) \cdot v}$

$1.28 \times 10^{-18} = \frac{1}{2}(9.1 \times 10^{-31}) \cdot v^2$

$v = 1677255.739$ $= 4.3438 \times 10^{-10}\,\text{m}\left(\frac{10^9\,\text{nm}}{1\text{m}}\right)$

Answer: 0.43 nm

[1 point] (e) What kind of waves are used in MRIs to knock spinning protons out of alignment with the external magnetic field? [ ] Gamma rays [ ] X-rays [✓] Ultraviolet [ ] Microwave [ ] Radio