Answers to Exam 3

Multiple choice Questions

[1] [D] Mary's far point is 6 meters. Thus the image from objects at infinity [$d_o = \infty$] need to made at 6 meters. Since image is formed on object side, image is virtual.

$$\frac{1}{d_o} = 0 \Rightarrow \frac{1}{i} = \frac{1}{f} \quad \text{and } d_i = -6\,m, \text{ so } f = -6\,m$$

[2] [A] Mary is also "far sighted" (not unusual to be both in older people. She needs images of near object to be formed at 1 meter, her near point. Image is also virtual

$$d_o = 0.20\,m, \; d_i = -1\,m$$

$$f = \frac{d_o d_i}{d_o + d_i} = \frac{0.2\,m \times (-1\,m)}{0.2\,m - 1\,m} = \frac{-0.2\,m^2}{-0.8\,m} = +\frac{1}{4}\,m$$

$$f = +0.25\,m.$$

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[3] [C] Telescopes require two properties: magnification $= \frac{f_o}{f_e}$, and amount of light gathered, proportional to area of lens (or mirror)

So best combination is $f_o = 100\,cm$, $f_e = 1\,cm$, and $D = 10\,cm$

$(f_o, f_e) = (2, 5)$

[4] [E] Magnification of microscope is proportional to $\frac{1}{f_o f_e}$. So the lenses with the two shortest focal lengths make the best combination. Usually better to have the shortest focal length as objective, but it will work both ways.

(5, 4) [or (4, 5)]

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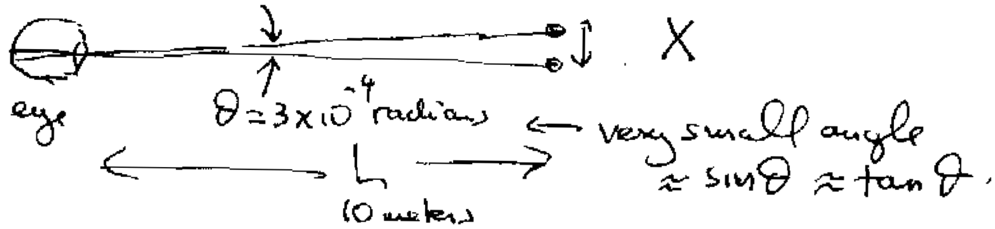
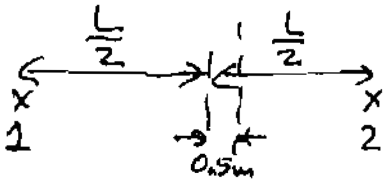
[5] [C]



θ is given, so $X = L\theta = 10\,m \times 3 \times 10^{-4}\,\text{radians} = 3 \times 10^{-3}\,m$
$= 3\,mm.$

6 D



To hear nothing waves have to be π out of phase (180° or $\frac{1}{2}\lambda$)

So $\left(\frac{L}{2}+0.5\,m\right)-\left(\frac{L}{2}-0.5\,m\right)=\frac{1}{2}\lambda$

$1\,m=\frac{1}{2}\lambda \Rightarrow \lambda = 2\times 1m = 2m.$

— o —

7 D Single slit "zeros" occur when $W\sin\theta = m\lambda$

or $\sin\theta = \frac{m\lambda}{W} = \frac{m\times 600\,nm}{1600\,nm}$

So maximum m possible is 2. (if 3, $\sin\theta = \frac{18}{16}$!)

There are two zeroes to each side of center, (peaks decrease in amplitude

8 A For ideal two slits, maximum occur when $d\sin\theta = m\lambda$

$\sin\theta = \frac{m\lambda}{d} = \frac{m\,600}{1600}$ ← again 2 orders are possible, of equal intensity.

— o —

9 C $\lambda_{peak}T = \text{constant} \Rightarrow \frac{500\,nm\times 5800\,K}{300\,K} = 9666.7\,nm.$

or $\approx 9670\,nm$.

This is the infrared (this is the way "night vision" goggles work)

— o —

10 B Neutrons are particles with mass

$KE = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$, not $\frac{hc}{\lambda}$

— o —

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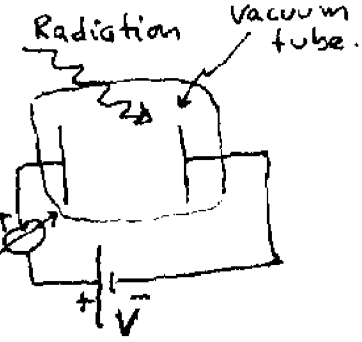
In this and next problem, please write neatly and show all your work. No credit just for a numerical answer without showing how you got it.

Problem 1 (25 points). A 10^{-3} Watts laser emits radiation of a single wavelength. The radiation is used to emit electrons from a metal electrode, connected to a battery as shown in the picture. The battery provides a potential difference of 2 Volts, which is the minimum potential difference needed to stop all the electrons emitted from the metal surface. The work function of the metal is $W_0 = 3$ eV.



A. (10 points) Calculate the wavelength of the laser radiation.

Einstein's equation

$$\frac{hc}{\lambda} = W_0 + KE = 3eV + 2eV = 5eV$$

$$\lambda = \frac{hc}{5eV} = \frac{6.65\times10^{-34}\,Js \times 3\times10^{8}\,m/s}{5eV \times 1.6\times10^{-19}\,\frac{J}{eV}}$$

$$= 2.49\times10^{-7}\,m \cong 249\,nm.$$

B. (7 points) Calculate how many photons arrive at the metal electrode in one second. If you don't trust your result for part A, use $\lambda = 300$ nm.

$$\frac{\text{number of photons}}{\text{second}} = \frac{10^{-3}\,\text{Watts}}{\frac{hc}{\lambda}} = \frac{10^{-3}\,W \times 2.49\times10^{-7}\,m}{6.65\times10^{-34}\,Js \times 3\times10^{8}\,m/s} = 1.25\times10^{15}\,\frac{\text{photons}}{s}$$

[1.51×10^{15} photons/s for 300 nm]

C. (5 points) For this part, assume that the battery in the circuit is reversed and all the emitted electrons are collected in the left electrode. Calculate the current in the circuit, in Amperes, assuming 100% efficiency in ejecting electrons.

[or 2.4×10^{-4}A for λ = 300 nm wavelength]

$$1.25\times10^{15}\,\frac{\text{electrons}}{\text{second}} \times 1.6\times10^{-19}\,\frac{\text{Coulombs}}{\text{electron}} = 2\times10^{-4}\,\text{Amperes}$$

Problem, Part C, can be solved also by realizing that electron "see's" "5 Volts" applied to it (it uses 3 Volts to get out of the metal and 2 Volts potential difference to go to the other electrode -

$$\text{so Current} = \frac{\text{Power}}{\text{Potential difference}} = \frac{10^{-3}\,\text{Watts}}{5\,\text{Volts}} = 2\times10^{-4}\,A$$

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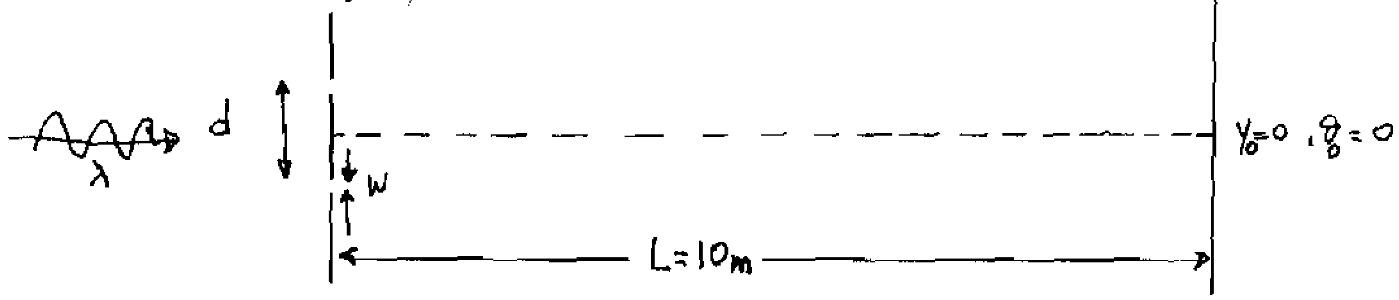
Problem 2 (25 points). Light with $\lambda = 600$ nm strikes at normal incidence a two-slit system as shown in the sketch below. The separation between the slits is $d = 2500$ nm. For parts (a), (b), and (c) ignore the slits width (W), assuming that they are "ideal" and radiate uniformly in all directions.



(a) (5 points) Calculate how many "orders" (interference maxima) are possible between $\theta = 0^0$ and $\theta = 90^0$

$$\sin\theta = \frac{m\lambda}{d} = \frac{m\ 600\,\text{nm}}{2500\,\text{nm}} = \frac{m}{4.16}$$

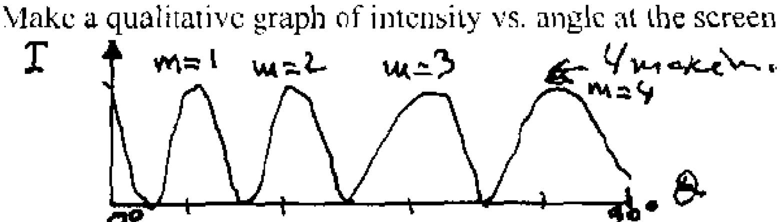
So largest $m = 4$. One sees 4 orders.

(b) (6 points) Calculate the distance $y_3 - y_0$ between the third interference maximum and the center of the screen (central maximum)

for $m = 3$: $\sin\theta = \frac{3 \times 600}{2500} = 0.720$ ← large angle. $\theta = 46.1^\circ$

$y = L\tan\theta = 10\,\text{m}\,\tan 46.1^\circ = 10.4\,\text{m}$!

(c) (6 points) Make a qualitative graph of intensity vs. angle at the screen



(d) (8 points) Imagine now that $W = (1/3)\,d$. Is any order of the two-slit interference pattern missing? Explain and make a very qualitative graph of what the intensity vs. angle at the screen should now look like.

Single slit diffraction produces "zeros" of intensity when $\sin\theta = \frac{n\lambda}{W} = \frac{n\ 600\,\text{nm}}{\frac{1}{3}d} = \frac{n \times 1800\,\text{nm}}{2500\,\text{nm}}$

So there is one zero, $n=1$, which coincides with the $m=3$ interference maximum. So the $m=3$ maximum is missing