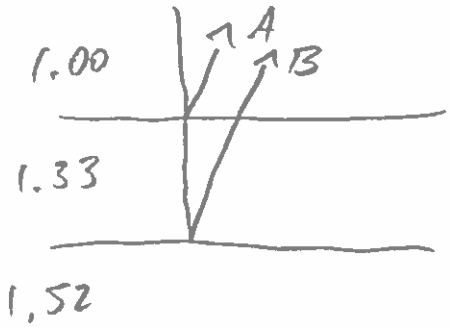
Physics 10164 - Spring 2019 Exam 4A

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (25 pts) A uniform layer of water (n = 1.33) is 485 nm thick and lies on a glass plate (n = 1.52). Light shines perpendicularly on this layer. What wavelengths of light in the visible range (between 400 and 700 nm) experience constructive interference upon reflection from this surface?



$\phi_A = \frac{1}{2}$

$\phi_B = \frac{2nt}{\lambda_0} + \frac{1}{2}$

$\Delta\phi = \frac{2nt}{\lambda_0} = 0, 1, 2, 3, \ldots$

$\frac{2nt}{\lambda_0} = 0$ x

$\frac{2nt}{\lambda_0} = 1 \Rightarrow \lambda_0 = 2nt = 1290\,nm$ x

$\frac{2nt}{\lambda_0} = 2 \Rightarrow \lambda_0 = \frac{2nt}{2} = 645\,nm$ ✓

$\frac{2nt}{\lambda_0} = 3 \Rightarrow \lambda_0 = \frac{2nt}{3} = 430\,nm$ ✓

$\frac{2nt}{\lambda_0} = 4 \Rightarrow \lambda_0 = \frac{2nt}{4} = 322\,nm$ x

2. (25 pts) While driving at night on a highway, a car speeds by you and moves away into the distance in front of you. Under these conditions, the pupils of your eyes (circular apertures) have diameters of 6.8 mm. The tail lights of the car are separated by a distance of 1.4 meters and emit red light (646 nm).

a) How far away from you is this car when its tail lights appear to merge into a single spot of light due to the effects of diffraction?

b) If your retina is located 2.5 cm behind your pupil, what is the full width of the central maximum of the diffraction pattern caused by the image of the car's lights?

$$\frac{\text{sep}}{\text{distance}} = \frac{1.22\lambda}{D}$$

$$\frac{1.4}{d} = \frac{1.22(646\times10^{-9})}{6.8\times10^{-3}} = 1.159\times10^{-4}$$

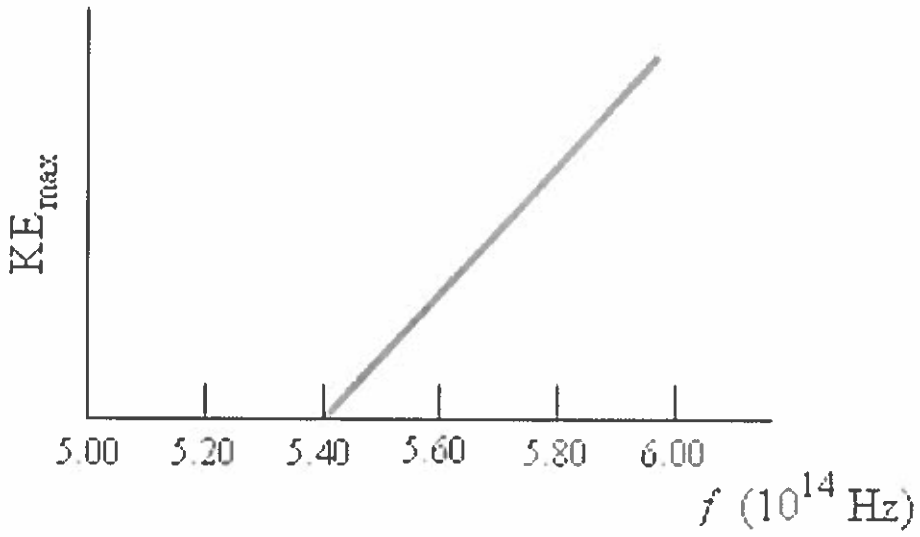
$$d = \frac{1.4}{1.159\times10^{-4}} = \boxed{1.2\times10^{4}\ m} = 7.5 \text{ miles}$$

b) $\frac{ay}{L} = \lambda$ for 1st min

$$y = \frac{L\lambda}{a} = \frac{(.025)(646\times10^{-9})}{6.8\times10^{-3}} = 2.375\times10^{-6}$$

$$\text{full width} = 2y = \boxed{4.8\times10^{-6}\ m}$$

3. (25 pts) The results of a photoelectric experiment are illustrated in the drawing below. During the experiment, incident light is used that has a wavelength of 515 nm. What is the maximum velocity of the ejected electrons under these conditions?



At $f = 5.40 \times 10^{14}$ Hz, $(KE)_{max} = 0$

So $\phi = hf = (6.626 \times 10^{-34})(5.40 \times 10^{14})$

$= 3.578 \times 10^{-19}$ J $= 2.236$ eV

$$(KE)_{max} = \frac{hc}{\lambda} - \phi$$

$$= \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{515 \times 10^{-9}} - 2.236$$

$= 3.86 \times 10^{-19}$ J $- 2.236$ eV

$= 2.412 - 2.236 = 0.176$ eV

$\Rightarrow 2.82 \times 10^{-20}$ J $= \frac{1}{2}(9.11 \times 10^{-31}) v^2$

$$\boxed{v = 2.49 \times 10^{5} \text{ m/s}}$$

4. (25 pts) Carbon-14 has a half-life is 5730 years. An ancient piece of wood is discovered with an activity is 0.14 Bq per gram of Carbon. What is the age of this sample, in years?

8.3×10^{11} C-12 per C-14 atom.

$T_{1/2} = 5730 \text{ yr} = 1.81 \times 10^{11} \text{ s}$

$$\lambda = \frac{0.693}{1.81 \times 10^{11}} = 3.83 \times 10^{-12} \text{ s}^{-1}$$

$1 \text{ gram} = .001 \text{ kg} = N_c m_c$

$$M_c = 12.0 \text{ u} * 1.66 \times 10^{-27} \frac{\text{kg}}{\text{u}} = 1.99 \times 10^{-26} \text{ kg}$$

$$N_c = \frac{.001}{1.99 \times 10^{-26}} = 5.02 \times 10^{22} \text{ atoms C-12}$$

$$\Rightarrow 6.05 \times 10^{10} \text{ atoms C-14}$$

$$a_0 = \lambda N_0 = (3.83 \times 10^{-12})(6.05 \times 10^{10})$$

$$= 0.232$$

$$0.14 = 0.232 \, e^{-\lambda t}$$

$$0.6044 = e^{-\lambda t}$$

$$-0.5034 = -(3.83 \times 10^{-12}) t$$

$$t = 1.31 \times 10^{11} \text{ s} = \boxed{4200 \text{ yr}}$$