Physics 10164 - Spring 2019 Exam 4D

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 light source illuminates two parallel slits separated by a distance d. One point on the screen where two rays meet is the 3rd minimum, counted relative to the central bright fringe. The difference in distances travelled by the two rays is 855 nm (ray 2 travels a little further than ray 1).

a) What is the wavelength (in nm) of the incident light?

b) If the slit separation d = 5.50 x 10^{-6} m, what angle θ do the rays make with the horizontal?

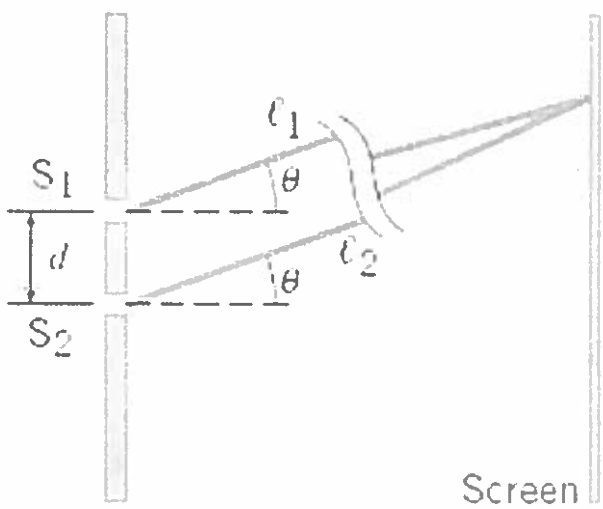
a) 1st min: $\delta = \frac{\lambda}{2}$

2nd min: $\delta = 3\lambda/2$

3rd min: $\delta = 5\lambda/2$

$855\ nm = 5\lambda/2$

$\boxed{\lambda = 342\ nm}$

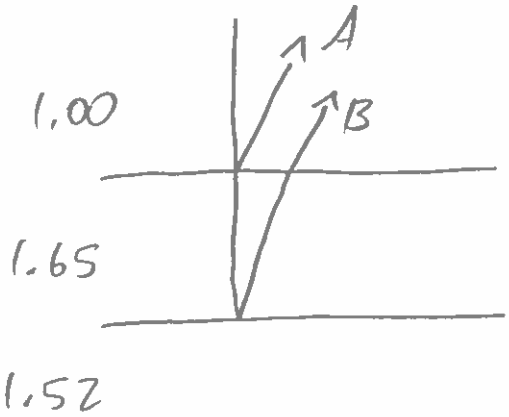


b) $d \sin\theta = 855\ nm$

$\sin\theta = \frac{855\ nm}{5.5 \times 10^{-6}} = 0.155$

$\boxed{\theta = 8.94°}$

2. (25 pts) You are standing in air and looking a flat piece of glass
(n = 1.52) on which there is a thin 422 nm film of transparent plastic (n = 1.65). Light is incident on the coated glass and reflects back, appearing dark. For what wavelengths of light in the visible range (400 - 700 nm) could this be true?



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

$$\phi_B = \frac{2nt}{\lambda_0} + 0$$

$$\phi_B - \phi_A = \frac{2nt}{\lambda_0} - \frac{1}{2} = \frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \ldots$$

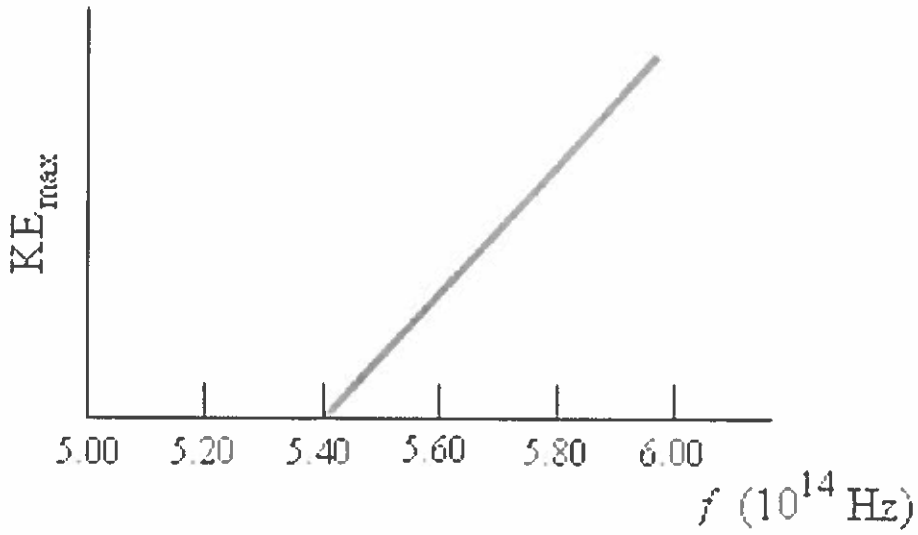
$$\frac{2nt}{\lambda_0} - \frac{1}{2} = \frac{1}{2} \Rightarrow \frac{2nt}{\lambda_0} = 1 \Rightarrow \lambda_0 = 2nt = 1393\text{ nm} \times$$

$$\frac{2nt}{\lambda_0} - \frac{1}{2} = \frac{3}{2} \Rightarrow \frac{2nt}{\lambda_0} = 2 \Rightarrow \lambda_0 = \frac{2nt}{2} = 696\text{ nm} \checkmark$$

$$\frac{2nt}{\lambda_0} - \frac{1}{2} = \frac{5}{2} \Rightarrow \frac{2nt}{\lambda_0} = 3 \Rightarrow \lambda_0 = \frac{2nt}{3} = 464\text{ nm} \checkmark$$

$$\frac{2nt}{\lambda_0} - \frac{1}{2} = \frac{7}{2} \Rightarrow \frac{2nt}{\lambda_0} = 4 \Rightarrow \lambda_0 = \frac{2nt}{4} = 348\text{ nm} \times$$

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.

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

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

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

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

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

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

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

$$= 0.232$$

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

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

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

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