Physics 10164 - Spring 2019 Exam 4E

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) Two light sources illuminate a screen with two parallel slits. Light source A has a wavelength of 523 nm. Light source B has an unknown wavelength. On a viewing screen, light source A produces its third bright fringe at the same place where the light from source B produces its fourth dark fringe. The fringes are counted relative to the central (zeroth) bright fringe. What is the unknown wavelength?

1st dark: $\frac{\lambda}{2}$

2nd dark: $\frac{3\lambda}{2}$

3rd dark: $\frac{5\lambda}{2}$

4th dark: $\frac{7\lambda}{2}$

A: $d \sin\theta = 3\lambda_A$

B: $d \sin\theta = \frac{7}{2}\lambda_B$

$$3\lambda_A = \frac{7}{2}\lambda_B$$

$$\frac{3(523\ \text{nm})}{3.5} = \lambda_B$$

$$\boxed{\lambda_B = 448\ \text{nm}}$$

2. (25 pts) A diffraction grating contains 2200 lines/cm. When used with light of a certain wavelength, a third-order maximum is formed at an angle of 25°.

a) What is the wavelength of this light?
b) How many complete orders of visible light (400 - 700 nm) are visible upon reflecting from this diffraction grating?

$$d = \frac{1}{n} = \frac{1\ \text{cm}}{2200\ \text{lines}} \cdot \frac{1\ \text{m}}{100\ \text{cm}} = 4.545 \times 10^{-6}\ \text{m}$$

a) 3rd-order max: $d \sin\theta = 3\lambda$

$$\lambda = \frac{d \sin\theta}{3} = \boxed{640\ \text{nm}}$$

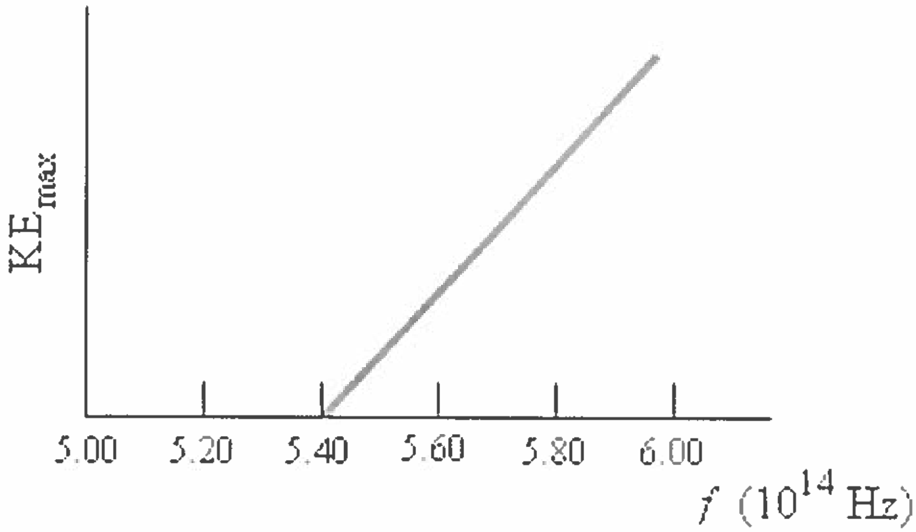
b) For what m does $\theta = 90°$?

$d \sin 90° = m\lambda$ assume red light since it has biggest θ

$$m = \frac{d}{\lambda} = 6.49$$

so $\boxed{\text{6 complete orders visible}}$

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) One possible Uranium fission reaction is

$^{1}n + {}^{235}U \rightarrow {}^{94}Zr + {}^{139}Te + 3\ {}^{1}n$ + energy

We will assume the masses of these nuclei are:

neutron (^{1}n) = 1.008665 u
Uranium (^{235}U) = 235.043924 u
Zirconium (^{94}Zr) = 93.906315 u
Tellurium (^{139}Te) = 138.934730 u

a) How much energy is produced by this reaction (in MeV)?
b) How much mass (in kg) of Uranium would be necessary in 1 year to power a house that uses 2200 kw-hr of energy per month, assuming this is the reaction that provides the power?

a) $\Delta m = 236.052589 - 235.867040$

$= 0.185549$

$\boxed{E = 170\ MeV} = 2.77 \times 10^{-11}\ J$

b) $E_{tot} = \left[\frac{2200\ kw\text{-}hr}{month} \cdot \frac{12\ months}{year} \cdot \frac{3.60 \times 10^{6}\ J}{kW \cdot hr}\right] \cdot 1\ year$

$= 9.5 \times 10^{10}\ J$

$E_{tot} = N_{reac} E_{reac}$

$N = \frac{9.5 \times 10^{10}}{2.77 \times 10^{-11}} = 3.43 \times 10^{21}$

$M_{tot} = N_U m_U = (3.43 \times 10^{21})(235\ u)(1.66 \times 10^{-27} \frac{kg}{u})$

$= \boxed{1.3 \times 10^{-3}\ kg}$