Physics 10164 - Spring 2019 Exam 4B

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?

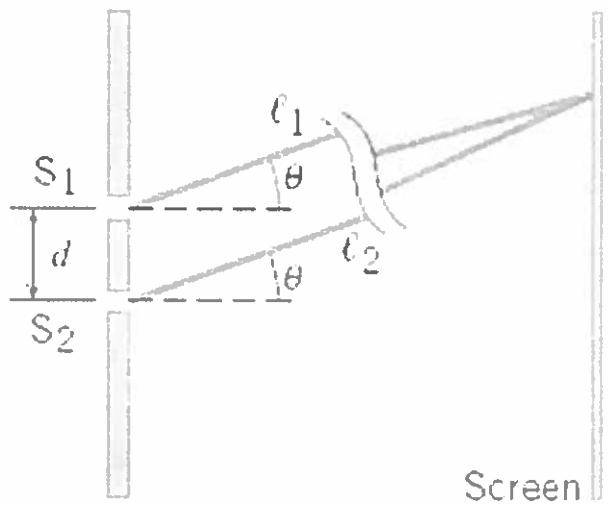
a) 1st min: $\delta = \frac{\lambda}{2}$

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

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

$855\ nm = 5\lambda/2$

$\lambda = 342\ nm$



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

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

$\theta = 8.94°$

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?

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

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

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

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

3. (25 pts) A hydrogen atom's electron is in energy level n = 5, and a photon is emitted by the electron. Determine (a) the energy and wavelength of the photon that has the shortest possible wavelength. Also, determine (b) the energy and wavelength of the photon that has the longest possible wavelength. Answer this question with 3 SF.

a) Shortest λ = biggest ΔE (5 → 1)

$$E = 13.6\left(\frac{1}{1} - \frac{1}{25}\right) = \boxed{13.1\ eV}$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{1} - \frac{1}{25}\right) \Rightarrow \boxed{\lambda = 95.0\ nm}$$

b) Longest λ = smallest ΔE (5 → 4)

$$E = 13.6\left(\frac{1}{16} - \frac{1}{25}\right) = \boxed{0.306\ eV}$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left(\frac{1}{16} - \frac{1}{25}\right) \Rightarrow \boxed{\lambda = 4050\ nm}$$

4. (25 pts) One possible Uranium fission reaction is

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

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 to power a house that uses 2200 kw-hr of energy per month, assuming this is the reaction that provides the power?

in 1 year

a) $\Delta m = 236.052589 - 235.867040$

$= 0.185549$

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

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

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

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

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

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

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