Physics 10164 - 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.

(30 pts) Light of wavelength 634 nm illuminates a single slit of width 0.54 mm.

(a) At what distance from the slit should a screen be placed if the first minimum in the diffraction pattern to be 1.1 mm away from the central maximum?

(b) If a shorter wavelength of light is used to illuminate the slit, will the central maximum of the pattern get broader, narrower or remain the same size? Justify your answer.

a) $a \sin\theta = \lambda$ for 1st minimum

$$\frac{ay}{L} = \lambda \quad \Rightarrow L = \frac{ay}{\lambda} = \frac{(.54\times10^{-3})(1.1\times10^{-3})}{634\times10^{-9}}$$

$$= \boxed{0.94\,m}$$

b) Since $y = \frac{\lambda L}{a}$, $y \propto \lambda$

If $\lambda\downarrow$, then $y\downarrow$ (narrower)

2. (30 pts) The following are four possible transitions for a hydrogen atom:

A: n = 2 -> 5 ← abs
B: n = 3 -> 6 ← abs
C: n = 4 -> 1 ← emit
D: n = 7 -> 2 ← emit

a) Which transition will cause the atom to EMIT the shortest wavelength photon? What is that wavelength?

b) Which transition will cause the atom to ABSORB the longest wavelength photon? What is that wavelength?

c) Which transition represents the atom's electron LOSING the most energy? How much energy (eV) does the electron lose?

a) For C+D, $\frac{1}{\lambda_C} = R_H\left(\frac{1}{1^2} - \frac{1}{4^2}\right) =$

$= (1.097\times10^7)(1 - \frac{1}{16}) = 1.03\times10^7$

→ $\lambda_C = 97.2\,nm$

$\frac{1}{\lambda_D} = R_H\left(\frac{1}{2^2} - \frac{1}{7^2}\right)$

$= (1.097\times10^7)(\frac{1}{4} - \frac{1}{49}) = 2.52\times10^6$

$\lambda_D = 397\,nm$

b) For A+B: $\frac{1}{\lambda_A} = (1.097\times10^7)(\frac{1}{4} - \frac{1}{25}) = 2.30\times10^6$

$\lambda_A = 434\,nm$

$\frac{1}{\lambda_B} = (1.097\times10^7)(\frac{1}{9} - \frac{1}{36}) = 9.14\times10^5$

→ $\lambda_B = 1094\,nm$

c) Losing energy = emission (C or D)

Since λ_C smaller, $E \propto \frac{1}{\lambda}$, most energy, C

$\Delta E = \left(-\frac{13.6}{16} - \left(-\frac{13.6}{1}\right)\right) = 12.8\,eV$

3. (35 pts) A nuclear reactor provides energy using the nuclear reaction: Pu-239 -> U-235 + He-4, where

Mass of Pu-239 = 239.052156 amu
Mass of U-235 = 235.043923 amu
Mass of He-4 = 4.002602 amu

A space probe is designed to last for at least 40 years during which time the reactor provides an average power of 1500 Watts. How many kg of Pu-239 would be needed for the spacecraft, assuming it is all used up during this time?

$$E_{TOT} = N_{reac} E_{reac}$$

$$E_{TOT} = \frac{1500\ J}{sec} \cdot 40\ yrs \cdot \frac{3.16 \times 10^7\ s}{yr}$$

$$= 1.896 \times 10^{12}\ J$$

$$E_{reac} = \Delta m c^2$$

$$= (m_{in} - m_{out})c^2$$

$$= (239.052156 - 235.043923 - 4.002602)c^2$$

$$= (.005631\ u)c^2 \cdot \frac{931.5\ MeV}{c^2}$$

$$= 5.245\ MeV \cdot \frac{1.6 \times 10^{-13}\ J}{MeV} = 8.4 \times 10^{-13}\ J$$

$$N_{reac} = \frac{1.896 \times 10^{12}}{8.4 \times 10^{-13}} = 2.26 \times 10^{24}\ \text{atoms}$$

$$M_{TOT} = N_{reac} m_{atom} = (2.26 \times 10^{24})(239\ u)\left(\frac{1.66 \times 10^{-27}\ kg}{u}\right)$$

$$= \boxed{0.90\ kg}$$