Physics 10164 - Exam 5B

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 rocket ship travels to the distant star Rigel, 450 light years away as measured in Earth's rest frame, at a velocity of 0.98c. 1 light year = 9.46×10^{15} meters.

a) How much time does this trip take as measured in Earth's frame?
b) How much time does the trip take in the ship's frame?
c) How far does the ship travel, as measured by the ship's odometer, in light years?

a) $t_E = \frac{d_E}{v} = \frac{450\ ly}{.98\ c} =$ **460 years**

b) $t_{rocket} = \frac{t_{Earth}}{\gamma}$ $\gamma = \frac{1}{\sqrt{1-.98^2}} = 5.025$

$= \frac{460}{5.025} =$ **92 years**

c) $d_{ship} = (.98)(92) =$ **90 light years**

2. (25 pts) The Balmer-alpha transition involves a photon being emitted as an electron drops from level n = 3 --> 2.

a) What is the energy (in eV) of the emitted photon?

b) How many atoms are necessary to emit a total energy of 4.4 x 10^{-12} Joules?

$$E_3 = -\frac{13.6}{9} = -1.51\,eV$$

$$E_2 = -\frac{13.6}{4} = -3.40\,eV$$

$$\Delta E = -1.51 - (-3.40) = 1.89\,eV$$

b) $\Delta E = 3.024 \times 10^{-19}\,J$

$$E_{TOT} = N E_\gamma$$

$$N = \frac{4.4 \times 10^{-12}}{3.02 \times 10^{-19}} = 1.5 \times 10^{7} \text{ atoms}$$

3. (25 pts) An alpha particle (with a charge of +2e and a mass of 4.002602 amu) is fired at a fix gold nucleus target (+79e charge). The alpha particle gets to a minimum distance of 7.2 x 10^{-15} meters before turning around. What is the initial velocity of the alpha particle when fired at the nucleus from a very large distance?

$$U_i + K_i = U_f + K_f$$

$$U_i = 0 \text{ at } r = \infty$$

$$U_f = \frac{kq_1q_2}{r_{min}} = \frac{(9\times10^9)(2)(1.6\times10^{-19})(79)(1.6\times10^{-19})}{7.2\times10^{-15}}$$

$$= 5.056\times10^{-12}\,J$$

$$K_i = \frac{1}{2}mv^2$$

$$K_f = 0$$

$$m = (4.002602\,u)(1.66\times10^{-27}\,kg/u)$$
$$= 6.64\times10^{-27}\,kg$$

$$\frac{1}{2}(6.64\times10^{-27})v^2 = 5.056\times10^{-12}$$

$$v = 3.9\times10^7\,m/s$$

4. (25 pts) A ceramic Plutonium-239 pellet will be used to power a spacecraft that uses 750 Watts for the spacecraft's 40 year lifetime. The primary reaction used will be alpha decay:

$^{239}Pu \rightarrow {}^{235}U + {}^{4}He$

How many grams of Plutonium will be needed for the lifetime of the spacecraft?

Plutonium mass = 239.052156 amu
Uranium mass = 235.043923 amu
Helium mass = 4.002602 amu

$$E_{TOT} = 750\ J/s \cdot 40\ yr \cdot 3.16\times10^{7}\ s/yr$$

$$= 9.48\times10^{11}\ J$$

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

$$= (239.052156 - 235.043923 - 4.002602)(931.5)$$

$$= (.005631)(931.5)$$

$$= 5.245\ MeV = 8.4\times10^{-13}\ J$$

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

$$N_{reac} = \frac{9.48\times10^{11}}{8.4\times10^{-13}} = 1.13\times10^{24}\ atoms$$

$$M_{TOT} = N m_{Pu} = 2.7\times10^{26}\ u = .448\ kg$$

or 450 grams