Physics 10164 - Exam 5

Each problem is worth 25 points. 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. According to an observer on the Earth, a ship flying by has a length of 75 meters. The pilot of the ship measures his ship to be 120 meters long.

a) How fast (as a fraction of c) is the ship moving?

b) How long will it taken the ship to travel the 450 million mile distance to Jupiter from the Earth, as measured by the observer on the Earth?

c) How long will the trip take as measured by the pilot?

a) $\gamma = \frac{120}{75} = 1.6 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$2.56 = \frac{1}{1-\frac{v^2}{c^2}}$

$2.56 - 2.56\frac{v^2}{c^2} = 1 \Rightarrow \frac{v^2}{c^2} = \frac{-1.56}{-2.56}$

$\boxed{v = 0.78c}$

b) $450 \times 10^6 \text{ mi} \cdot \frac{1609 \text{ m}}{1 \text{ mi}} = 7.24 \times 10^{11} \text{ m}$

$v = .78(3 \times 10^8) = 2.34 \times 10^8 \text{ m/s}$

$t = \boxed{3100 \text{ s}} = 0.86 \text{ hr}$

c) $t_{moving} = \frac{t_{rest}}{\gamma} = \boxed{1900 \text{ s}}$

2. What wavelength of light would have to fall on lithium (work function is 2.30 eV) if it is to emit electrons with a maximum speed of 3.0 x 10^6 m/s?

$$KE = \frac{1}{2} m v^2$$

$$= 4.1 \times 10^{-18}\ J = 25.6\ eV = \frac{hc}{\lambda} - \phi$$

$$\frac{hc}{\lambda} = 25.6\ eV + 2.3\ eV = 27.9\ eV$$

$$\lambda = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{4.47 \times 10^{-18}}$$

$$= 4.45 \times 10^{-8}\ m$$

or **44 nm**

3. A certain isotope of Americium has a half-life of 432 years and is often used in smoke detectors. The mass of a single atom of Americium is 241 amu.

a) What is the activity (in Curies) of 1.5 grams of Americium?

b) In how many years will the activity be reduced to 5.0% of its original value?

$241\ amu = 4.0 \times 10^{-25}\ kg$

$$N = \frac{1.5 \times 10^{-3}\ kg}{4.0 \times 10^{-25}\ kg} =$$

$$= 3.75 \times 10^{21}$$

$$T_{1/2} = 432\ yrs = 1.365 \times 10^{10}\ s$$

$$a = \lambda N = \frac{0.693}{1.365 \times 10^{10}} (3.75 \times 10^{21})$$

$$= 1.9 \times 10^{11}\ Bq \cdot \frac{2.7 \times 10^{-11}\ Ci}{1\ Bq}$$

$$= \boxed{5.1\ Ci}$$

b) $\lambda = 5.08 \times 10^{-11}$

$$0.05 = e^{-\lambda t}$$

$$-3.0 = -(5.08 \times 10^{-11}) t$$

$$t = 5.9 \times 10^{10}\ s = \boxed{1900\ yrs}$$

4. An example of a "clean" fusion reaction involves Hydrogen and Boron. Suppose we fuse a proton with Boron-11 (11.009306 u) to produce 3 Helium-4 nuclei (4.002602 u each).

a) How much energy (in MeV) is liberated per reaction?

b) How many reactions would be needed to generate 1.5 million kW-hr of energy, a rough estimate of the amount of energy TCU uses in a month?

c) What is the mass of Boron-11 needed in a month (in grams)?

a) $p + {}^{11}B \rightarrow 3\,{}^{4}He$

$M_{in} = 1.007276 + 11.009306 = 12.016582$

$m_{out} = 3(4.002602) = 12.007806$

$E = \Delta m c^2$

$= (.008776)(931.5\ \frac{MeV}{c^2}) = \boxed{8.2\ MeV}$ ↓ $1.3 \times 10^{-12}\ J$

b) $1.5 \times 10^6\ kW \cdot hr = 5.4 \times 10^{12}\ J$

$\#\ of\ reac = \frac{5.4 \times 10^{12}\ J}{1.3 \times 10^{-12}\ J/reac} = \boxed{4.2 \times 10^{24}}$

c) $Mass = (4.2 \times 10^{24})(11.009306\ amu)$

$= 4.57 \times 10^{25}\ u = .076\ kg$

or $\boxed{76\ grams}$