Physics 10164 - Exam 5A

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. (30 pts) A 350 meter long train is moving down a track so fast that it barely fits inside a 220 meter long tunnel.

a) How fast is the train moving, as a fraction of c?

b) How far does the train move, as measured by an observer standing at rest by the track, in 500 nanoseconds on the observer's watch?

c) While 500 nanoseconds passes in the trackside observer's frame, a passenger on board the train also measures how far the train travels. What does the passenger calculate?

$$\gamma = \frac{350}{220} = 1.59 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

a) $2.53 - 2.53\frac{v^2}{c^2} = 1$

$$\frac{v^2}{c^2} = -\frac{1.53}{-2.53} = 0.6045$$

$$\boxed{v = 0.78c}$$

b) $d = vt = (.78)(3\times10^8)(500\times10^{-9})$

$$= \boxed{120\ m}$$

c) $d = vt \qquad t_{train} = \frac{500\ ns}{\gamma} = 314.5\ ns$

$$d = (.78)(3\times10^8)(314.5\times10^{-9}) = \boxed{74\ m}$$

2. (30 pts) A metal surface is illuminated with light of wavelength 280 nm. The maximum kinetic energy of the ejected photoelectrons under this illumination is 1.72 eV.

a) What is the work function of the metal, in eV?

b) What is the cutoff wavelength of the metal, above which no electrons will escape?

a) $$\frac{hc}{\lambda} = \frac{(6.626\times10^{-34})(3\times10^{8})}{280\times10^{-9}} = 7.1\times10^{-19}\,J$$

$$= 4.44\,eV$$

$$(KE)_{max} = \frac{hc}{\lambda} - \phi$$

$$\phi = 4.44 - 1.72 = \boxed{2.72\,eV}$$

b) $$\frac{hc}{\lambda} = \phi$$

$$\lambda = \frac{hc}{\phi} = \frac{(6.626\times10^{-34})(3\times10^{8})}{(2.72)(1.6\times10^{-19})} =$$

$$= \boxed{457\,nm}$$

3. (40 pts) Cobalt-60 has an atomic mass of 58.9332 amu and a half-life of 5.27 years. It is a common by-product of a nuclear fission bomb. If a sample is contaminated with 2.5 grams of Co-60, how long will it take for the radioactivity of the sample to drop below a threshold of 3.0 μCi (micro-Curies, or 10^{-6} Curies)? Please answer <u>in years</u>.

$$T_{1/2} = 5.27\,yr = 1.66 \times 10^{8}\,s$$

$$\lambda = \frac{0.693}{1.66 \times 10^{8}} = \underline{4.16 \times 10^{-9}\,s^{-1}}$$

$$R = 3.0 \times 10^{-6}\,Ci \cdot \frac{3.7 \times 10^{10}\,Bq}{Ci}$$

$$= \underline{1.11 \times 10^{5}}$$

$$N = \frac{M_{Tot}}{M_{Co}} = \frac{2.5 \times 10^{-3}\,kg}{(58.9332)(1.66 \times 10^{-27}\,kg/u)}$$

$$= \underline{2.56 \times 10^{22}}$$

$$R_0 = \lambda N = (4.16 \times 10^{-9})(2.56 \times 10^{22})$$

$$= \underline{1.06 \times 10^{14}}$$

$$R = R_0 e^{-\lambda t}$$

$$1.11 \times 10^{5} = (1.06 \times 10^{14}) e^{-\lambda t}$$

$$1.04 \times 10^{-9} = e^{-\lambda t}$$

$$-20.7 = -(4.16 \times 10^{-9}) t$$

$$t = 4.97 \times 10^{9}\,s \cdot \frac{1\,yr}{3.16 \times 10^{7}\,s} = \boxed{160\ yrs}$$