Physics 10164 - Exam 5C

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 particle with an average lifetime of 0.77 seconds as measured in its own rest frame is fired along the circular path of a particle accelerator. It is measured to have a lifetime of 3.1 seconds in Earth's rest frame while moving at high speed.

a) What is the particle's velocity, expressed as a percentage of the speed of light?
b) How far do we observe the particle to travel in Earth's rest frame?
c) How far does the particle travel as measured in the particle's frame?

a) $\gamma = \frac{t_{rest}}{t_{moving}} = \frac{3.1}{0.77} = 4.026 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$16.2 = \frac{1}{1 - \frac{v^2}{c^2}}$

$16.2 - 16.2\frac{v^2}{c^2} = 1$

$\frac{v^2}{c^2} = \frac{15.2}{16.2}$

$v = 0.97c$

b) $d_E = v t_E = (.97)(3\times10^8)(3.1) = 9.0\times10^8\ m$

c) $d_{moving} = v t_{moving} = (.97)(3\times10^8)(.77) = 2.2\times10^8\ m$

2. (25 pts) A metal has a work function of 2.24 eV, and it is illuminated by light of wavelength 425 nm.

a) What is the maximum velocity with which electrons escape from the metal, or do they not escape?
b) What is the cutoff wavelength, above which electrons do not escape the metal? Answer in nm.

$\phi = 2.24\ eV$

a) $E_\gamma = \frac{(6.626\times10^{-34})(3\times10^{8})}{425\times10^{-9}\,m} = 4.68\times10^{-19}\,J$

$= 2.92\ eV$

$KE = E_\gamma - \phi = 0.68\ eV = 1.09\times10^{-19}\,J$

$\frac{1}{2}(9.11\times10^{-31})v^2 = 1.09\times10^{-19}$

$v = 4.90\times10^{5}\ m/s$

b) $\lambda_c \Rightarrow \frac{hc}{\lambda_c} = \phi$

$\frac{(6.626\times10^{-34})(3\times10^{8})}{\lambda_c} = 2.24\ eV$

$\lambda_c = \frac{(6.626\times10^{-34})(3\times10^{8})}{3.58\times10^{-19}\,J} = 5.55\times10^{-7}\,m$

$= 555\ nm$

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?

$$U_i + K_i = U_f + K_f$$

$U_i = 0$ 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) Strontium-90 has a mass of 90.0 amu and a half-life of 28.8 years.

a) What is the activity (in Curies) of 2.2 grams of Sr-90?
b) How many years will pass before the activity of the sample drops to 0.53% of its initial value?

$T_{1/2} = 28.8 \text{ yrs} = 9.1 \times 10^8 \text{ s}$

$\lambda = \frac{0.693}{T_{1/2}} = 7.61 \times 10^{-10}$

$N = \frac{m_{Tot}}{m_{Sr}} = \frac{.0022}{(90)(1.66 \times 10^{-27})}$

$= 1.47 \times 10^{22} \text{ atoms}$

$a = \lambda N = 1.12 \times 10^{13} \text{ Bq} \cdot \frac{1 \text{ Ci}}{3.7 \times 10^{10} \text{ Bq}}$

$= 303 \text{ Ci}$

b) $a = a_0 e^{-\lambda t}$

$.0053 = e^{-\lambda t}$

$-5.24 = -(7.61 \times 10^{-10}) t$

$t = 6.89 \times 10^9 \text{ s}$

$= 218 \text{ years}$