Name____

Physics 111 Quiz #6, March 2, 2018

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

____

Radioactive curium-242 decays by emission of an alpha particle (a helium nucleus) to be come more stable. The decay of curium to plutonium is shown below.

$$ {}^{242}_{96}Cm \rightarrow {}^{4}_{2}He + {}^{238}_{94}Pu $$

1. What is the kinetic energy of the emitted alpha particle? You may assume that the recoil of the plutonium is negligible and the kinetic energy of the curium is negligible. The spectroscopic masses of curium-242, the alpha particle and the plutonium-238 are $242.05884u$, $4.00260u$, and $238.04956u$ respectively.

$$ m_{Cm}c^2 = m_\alpha c^2 + K_\alpha + m_{Pu}c^2 $$

$$ \rightarrow K_\alpha = \left(m_{Cm} - m_\alpha - m_{Pu}\right)c^2 = \left(242.05884u - 4.00260u - 238.04956u\right)\times\left(\frac{931.5\frac{MeV}{c^2}}{1u}\right)c^2 $$

$$ K_\alpha = 6.222\,MeV = 9.955\times10^{-13}J $$

2. What are the speed and relativistic momentum of the ejected alpha particle?

$$ K_\alpha = (\gamma-1)mc^2 \rightarrow \gamma = 1+\frac{K_\alpha}{mc^2} \rightarrow \frac{1}{1-\frac{v^2}{c^2}} = \left(1+\frac{K_\alpha}{mc^2}\right)^2 \rightarrow 1-\frac{v^2}{c^2} = \frac{1}{\left(1+\frac{K_\alpha}{mc^2}\right)^2} $$

$$ v = \sqrt{1-\frac{1}{\left(1+\frac{K_\alpha}{mc^2}\right)^2}}\,c = \sqrt{1-\frac{1}{\left(1+\frac{6.222\,MeV}{\left(4.00260u\times\left(\frac{931.5\frac{MeV}{c^2}}{1u}\right)\right)c^2}\right)^2}}\,c = 0.058c $$

$$ p = \gamma mv = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{\left(4.00260u\times\left(\frac{931.5\frac{MeV}{c^2}}{1u}\right)\right)0.058c}{\sqrt{1-\frac{(0.058c)^2}{c^2}}} = 216.6\frac{MeV}{c} = 1.16\times10^{-19}\frac{kgm}{s} $$

3. If the recoil of the plutonium were taken into account the kinetic energy of the alpha particle would most likely

a. increase by $\frac{m_{Pu}+m_{He}}{m_{Pu}}$.

b. decrease by $\frac{m_{Pu}}{m_{Pu}+m_{He}}$.

c. remain the same.

d. would depend on external temperature and pressure of the system.

4. Satellites in orbit about the Earth can become charged by the photoelectric effect. Sunlight (which contains wavelengths of light from radio to x-ray) can eject electrons from the outer surface of the satellite and satellite designs need to minimize such charging. The charging of the satellite can ruin the sensitive microelectronics contained inside. Suppose a satellite is coated with platinum, which is a metal with a large work function. What is the maximum wavelength of light that can eject electrons from the platinum coating if $\phi = 5.32eV$?

$$K = hf - \phi = \frac{hc}{\lambda} - \phi \rightarrow 0 = \frac{hc}{\lambda_{\max}} - \phi$$

$$\rightarrow \lambda_{\max} = \frac{hc}{\phi} = \frac{6.63\times10^{-34}\,Js\times3\times10^{8}\,\frac{m}{s}}{5.32eV\times\frac{1.6\times10^{-19}\,J}{1eV}} = 2.34\times10^{-7}\,m = 234nm$$

5. The Sun is also a source of x-ray radiation. Suppose x-rays with a wavelength $\lambda = 5nm$ of strike the platinum coating of the satellite. Will electrons be ejected from platinum surface and if they are, what is the speed of an ejected electron? If electrons are not ejected from the platinum surface, explain why they will not be ejected.

$K = \frac{hc}{\lambda} - \phi = \left(\frac{6.63\times10^{-34}\,Js\times3\times10^{8}\,\frac{m}{s}}{5\times10^{-9}\,m}\times\frac{1eV}{1.6\times10^{-19}\,J}\right) - 5.32eV = 243.3eV$ and since this is positive, electrons will be ejected. The kinetic energy of these electrons is given by

$$K_\alpha = (\gamma - 1)mc^2$$

$$\rightarrow v = \sqrt{1 - \frac{1}{\left(1+\frac{K_\alpha}{mc^2}\right)^2}}\,c = \sqrt{1 - \frac{1}{\left(1+\frac{243.3eV}{\left(0.511\frac{MeV}{c^2}\right)c^2}\right)^2}}\,c = 0.031c\,.$$

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W = -q\Delta V_{f,i}$$

Magnetic Forces and Fields

$$F = qvB\sin\theta$$

$$F = IlB\sin\theta$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\tfrac{m}{s^2}$$

$$1e = 1.6\times10^{-19}C$$

$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\tfrac{Nm^2}{C^2}$$

$$\varepsilon_o = 8.85\times10^{-12}\tfrac{C^2}{Nm^2}$$

$$1eV = 1.6\times10^{-19}J$$

$$\mu_o = 4\pi\times10^{-7}\tfrac{Tm}{A}$$

$$c = 3\times10^8\tfrac{m}{s}$$

$$h = 6.63\times10^{-34}Js$$

$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$

$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$

$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$

$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$

$$N_A = 6.02\times10^{23}$$

$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t} = neAv_d;\ n = \frac{\rho N_A}{M}$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{charge}(t) = Q_{max}\left(1-e^{-\frac{t}{RC}}\right)$$

$$Q_{discharge}(t) = Q_{max}e^{-\frac{t}{RC}}$$

$$C_{parallel} = \sum_{i=1}^{N} C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{max} = hf - \phi = eV_{stop}$$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$

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

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

$$E_{total}^2 = p^2c^2 + m^2c^4$$

$$E_{rest} = mc^2$$

$$KE = (\gamma-1)mc^2$$

Geometry

$$Circles:\quad C = 2\pi r = \pi D \qquad A = \pi r^2$$

$$Triangles:\quad A = \tfrac{1}{2}bh$$

$$Spheres:\quad A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$$

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$

$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{max}^2 = c\frac{B_{max}^2}{2\mu_0}$$

$$P = \begin{cases} \frac{S}{c} = \frac{Force}{Area} \\ \frac{2S}{c} = \frac{Force}{Area} \end{cases}$$

$$S = S_o\cos^2\theta$$

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$

$$\theta_{inc} = \theta_{refl}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$M_{total} = \prod_{i=1}^{N} M_i$$

$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$

$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$

$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$