Name____

Physics 111 Quiz #7, March 9, 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.

____

Fluorine-18 (${}^{18}_{9}F$) is a positron emitter with a half-life of $109.8\,\text{min}$. This makes it an ideal agent to tag to a glucose (sugar) molecule. The fluorinated glucose can be injected into a patient and the subsequent gamma rays emitted from the patient as a result of the annihilation of the ejected positron and a nearby electron can be imaged. These annihilation event sites can be localized in space (i.e. the patient) and the images obtained form the basis of a PET, or positron emission tomographic scan, and PET scans are very useful in diagnosing cancer.

1. What is the radioactive decay sequence for fluorine?

$$ {}^{18}_{9}F \rightarrow {}^{0}_{+1}e + \overline{\upsilon}_e + {}^{18}_{8}O $$

2. What is the maximum kinetic energy available to the decay particles? Hint: Some of the following masses may be useful: ${}^{18}_{10}Ne$ $18.4752231u$; ${}^{18}_{9}F$ $18.0009380u$; ${}^{18}_{8}O$ $17.9991594u$; ${}^{14}_{7}N$ $14.0030740u$; e^- or e^+ $0.00054858u$; and ${}^{4}_{2}He$ $4.0026000u$.

$$ Q = \left(m_F - m_O - 2m_e\right)c^2 $$

$$ Q = \left\{\left(18.0009380u - 17.9991594u - 2\left(0.0005458u\right)\right) \times \frac{931.5\,\frac{MeV}{c^2}}{1u}\right\}c^2 $$

$$ Q = 0.635\,MeV $$

3. Suppose that a patient were injected with fluorinated glucose. If the patient has to wait an hour after injection, what fraction of initial source activity would be recorded?

$$ A = A_0 e^{-\lambda t} = A_0 e^{-\left(\frac{\ln 2}{t_{\frac{1}{2}}}\right)t} = A_0 e^{-\left(\frac{\ln 2}{109.8\,\text{min}}\right)60\,\text{min}} = 0.685A_0 \rightarrow 65.8\% $$

4. In the theory of beta decay, the neutrino was first predicted because of missing

   a. nuclear spin.
   b. angular momentum.
   c. energy.
   d. charge.

5. Suppose that your patient is an 80-year old male who has a history of prostate caner, and the results of this latest PET scan show evidence of the reoccurrence of the prostate cancer. To treat the cancer, suppose that you decide to implant radioactive seeds into the prostate. In this treatment, called brachytherapy, small seeds containing radioactive palladium-103 are implanted into the prostate and the subsequent radioactive decay of the palladium-103 atoms kills the tumor from the inside out. Palladium-103 emits x-rays with energy $21keV$. Assuming that a palladium atom is initially at rest, what is the recoil kinetic energy (in MeV) of the palladium-103 atom? The mass of palladium-103 is $102.906087u$.

$$p_i = p_f \rightarrow 0 = -p_x + p_{Pd} \rightarrow p_{Pd} = p_x = \frac{E}{c}$$

$$\frac{E}{c} = mv \rightarrow v = \frac{E}{mc} = \frac{0.021MeV}{\left(102.906087u \times \frac{931.5\frac{MeV}{c^2}}{1u}\right)c} = 2.19 \times 10^{-7}c$$

$$K = \tfrac{1}{2}mv^2 = \tfrac{1}{2}\left(102.906087u \times \frac{931.5\frac{MeV}{c^2}}{1u}\right)\left(2.19 \times 10^{-7}c\right)^2 = 2.3 \times 10^{-9}MeV$$

$$\therefore K = 2.3 \times 10^{-3}eV$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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