Name____

Physics 111 Quiz #6, November 14, 2014

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.

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A technique used to determine the age of dinosaur bones is the radiometric dating of igneous (previously molten) rocks in layers of earth that were deposited at or around the same time as the dinosaur died. The technique is known as rubidium-strontium dating. The rubidium isotope $^{87}_{37}Rb$ has a 48.8 billion year half-life and $^{87}_{37}Rb$ decays into $^{87}_{38}Sr$. You want to make an estimate of the age of the a dinosaur bone that you found, so you take an igneous rock sample that you dug up in the same area as the dinosaur bone to a geologist. After analysis the geologist tells you the ratio of strontium to rubidium found in the rock sample today is $\frac{^{87}_{37}Sr}{^{87}_{38}Rb} = 0.00127$.

a. What is the nuclear binding energy of $^{87}_{38}Sr$? (Hint: The mass of a proton and a neutron are $1.00727u$ and $1.00867u$ respectively.) (3 points)

$$\Delta E_{binding} = E_{parts} - E_{assembled\,atom} = m_{parts}c^2 - m_{assembled\,atom}c^2$$
$$\Delta E_{binding} = \left[Zm_{hydrogen} + (A-Z)m_{neutron}\right]c^2 - m_{assembled\,atom}c^2$$
$$\Delta E_{binding} = \left[\left(38\times 1.00727u + 49\times 1.00867\right)\times\frac{931.5\,\frac{MeV}{c^2}}{1u}\right]c^2 - \left[\left(86.908884u\right)\times\frac{931.5\,\frac{MeV}{c^2}}{1u}\right]c^2$$
$$\Delta E_{binding} = 738\,MeV$$

b. In the decay of rubidium to strontium, what is the particle emitted during the decay and what kinetic energy (in *keV*) is available for this particle? (Hints: The spectroscopic masses of the daughter and parent atoms are $M_{^{87}_{38}Sr} = 86.908884u$ and $M_{^{87}_{37}Rb} = 86.909187u$, respectively. Further, assume that the parent and daughter atoms are at rest before and after the decay and ignore the mass of the decay particle in your calculation.) (2points)

$$^{87}_{37}Rb \rightarrow {}^{87}_{38}Sr + {}^{0}_{-1}e$$

$$Q = m_{^{87}_{37}Rb}c^2 - m_{^{87}_{38}Sr}c^2 = \left(86.909187u - 86.908884u\right)\times\frac{931.5\,MeV}{1uc^2}c^2 = 0.282\,MeV$$

c. Write an expression for how the number of ${}^{87}_{37}Rb$ atoms changes as a function of time, assuming that we started some time in the past with $N_{0,{}^{87}_{37}Rb}$ atoms and that today we have $N_{today,{}^{87}_{37}Rb}$. (2 points)

$$N_{today,{}^{87}_{37}Rb} = N_{0,{}^{87}_{37}Rb}e^{-\lambda_{{}^{87}_{37}Rb}t}$$

d. What is the expression that relates the total number of strontium and rubidium atoms today, $N_{today,{}^{87}_{38}Sr} + N_{today,{}^{87}_{37}Rb}$ to the original number of rubidium atoms $N_{0,{}^{87}_{37}Rb}$ at some time in the past? Express your answer to *part c* in terms of this expression and calculate the age of the solidified igneous rock and hence an approximate age of the dinosaur bone you found. (3 points)

$$N_{0,{}^{87}_{37}Rb} = N_{today,{}^{87}_{38}Sr} + N_{today,{}^{87}_{37}Rb}$$

$$N_{today,{}^{87}_{37}Rb} = \left(N_{today,{}^{87}_{38}Sr} + N_{today,{}^{87}_{37}Rb}\right)e^{-\lambda_{{}^{87}_{37}Rb}t} \rightarrow \frac{N_{today,{}^{87}_{37}Rb}}{N_{today,{}^{87}_{38}Sr}} = \left(1+\frac{N_{today,{}^{87}_{37}Rb}}{N_{today,{}^{87}_{38}Sr}}\right)e^{-\lambda_{{}^{87}_{37}Rb}t}$$

$$\frac{1}{0.00127} = \left(1+\frac{1}{0.00127}\right)e^{-\frac{0.693}{48.8\times10^{9}\,yrs}t} \rightarrow 0.999 = e^{\frac{0.693}{48.8\times10^{9}\,yrs}t} \rightarrow t = 8.9\times10^{7}\,yrs = 89\,Myr$$

$t = 89$ million years

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

$$F = qvB\sin\theta$$
$$F = IlB\sin\theta$$
$$\tau = NIAB\sin\theta = \mu B\sin\theta$$
$$PE = -\mu B\cos\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$g = 9.8\,\frac{m}{s^2}$

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

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

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$d\sin\theta = m\lambda \text{ or } (m+\tfrac{1}{2})\lambda$$
$$a\sin\phi = m'\lambda$$

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m(v_f^2 - v_i^2) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$