

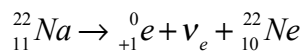
Name \_\_\_\_\_

Physics 111 Quiz #6, November 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.*

- a. Sodium-22 ( $^{22}_{11}\text{Na}$ ) is a positron emitter. What is the maximum decay energy available to the decay particles? Ignore the recoil of the daughter nucleus. Some masses for various elements are given in the table below.



Element	Mass (u)
$^{22}_{11}\text{Na}$	21.994437
$^{22}_{10}\text{Ne}$	21.991385
$^{22}_{12}\text{Mg}$	22.991385
$^4_2\text{He}$	4.00260
$^1_1\text{H}$	1.007828
$^1_1\text{p}$	1.00728
$^1_0\text{n}$	1.008665
$^0_{-1}e, ^0_{+1}e$	$5.49 \times 10^{-4}$

$$Q = K_e + K_{\nu_e} = (m_{\text{Na}} - m_{\text{Ne}} - 2m_e)c^2$$

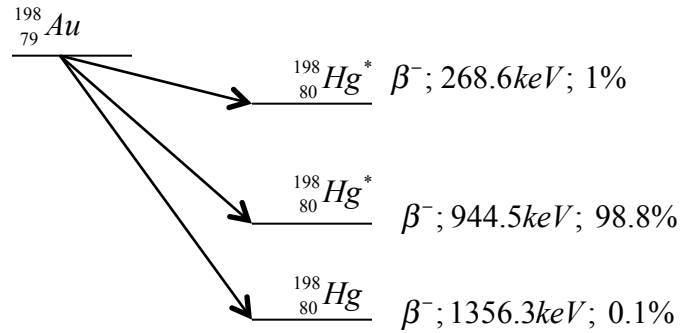
$$Q = \left[ (21.994437u - 21.991385u - 2 \times 5.49 \times 10^{-4}u) \times \frac{931.5 \frac{\text{MeV}}{c^2}}{1u} \right] c^2$$

$$Q = 1.820 \text{ MeV}$$

- b. Which of the following could be a possible emission of particles for the decay of  $^{238}_{92}\text{U}$  to  $^{206}_{82}\text{Pb}$ ?
1. 8 beta particles and 6 alpha particles.
  2. 6 beta particles and 4 alpha particles.
  3. 3 gamma ray photons, 6 alpha particles and 5 beta particles.
  4. 8 alpha particles and 6 beta particles.
  5. None of the above would describe the decay.

- c. The energy diagram for the decay of  $^{198}_{79}\text{Au}$  to stable  $^{198}_{80}\text{Hg}$  is shown below. Suppose that the gold decays by the most probably path shown in the diagram into a metastable state of  $^{198}_{80}\text{Hg}^*$ .

What photon energy would be emitted by the decay of  $^{198}_{80}\text{Hg}^*$  to  $^{198}_{80}\text{Hg}$ ?



$$E_{\gamma} = E_{\text{total}} - E_{\text{most probable}} = 1356.3 \text{ keV} - 944.5 \text{ keV} = 411.8 \text{ keV}$$

- d. What is the recoil kinetic energy of the  $^{198}_{80}\text{Hg}$  nucleus after the emission of the gamma ray photon? Assume that the speed of the recoiling  $^{198}_{80}\text{Hg}$  nucleus is not relativistic and that the rest energy is  $1.84 \times 10^5 \text{ MeV}$ .

$$\Delta p = 0 \rightarrow p_f = p_i \rightarrow -p_{\gamma} + p_{\text{Hg}} = 0 \rightarrow p_{\gamma} = p_{\text{Hg}} \rightarrow \frac{E_{\gamma}}{c} = m_{\text{Hg}} v_{\text{Hg}} \rightarrow \frac{E_{\gamma}}{m_{\text{Hg}} c} = v_{\text{Hg}}$$

$$K_{\text{Hg}} = \frac{1}{2} m_{\text{Hg}} \left( \frac{E_{\gamma}}{m_{\text{Hg}} c} \right)^2 = \frac{E_{\gamma}^2}{2 m_{\text{Hg}} c^2} = \frac{(0.4118 \text{ MeV})^2}{2 (1.84 \times 10^5 \text{ MeV})} = 4.61 \times 10^{-7} \text{ MeV}$$

- e. Suppose that the gamma ray photon from the decay of were used in a Compton effect experiment. If the incident gamma rays were scattered off of stationary electrons in a carbon target at an angle of  $90^\circ$  to the incident beam, what is the energy of the scattered gamma ray photons?

$$\lambda' = \lambda + \frac{h}{mc} (1 - \cos \phi) \rightarrow \frac{\lambda'}{hc} = \frac{\lambda}{hc} + \frac{1}{mc^2} (1 - \cos \phi)$$

$$\frac{1}{E'} = \frac{1}{E} + \frac{1}{mc^2} (1 - \cos \phi) = \frac{1}{0.4118 \text{ MeV}} + \frac{1}{(0.511 \frac{\text{MeV}}{c^2}) c^2} (1 - \cos 90)$$

$$E' = 0.228 \text{ MeV}$$

# Physics 111 Equation Sheet

## Electric Forces, Fields and Potentials

$$\vec{F} = k \frac{Q_1 Q_2}{r^2} \hat{r}$$

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

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

$$PE = k \frac{Q_1 Q_2}{r}$$

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

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

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

## Magnetic Forces and Fields

$$F = qvB \sin \theta$$

$$F = IlB \sin \theta$$

$$\tau = NIAB \sin \theta = \mu B \sin \theta$$

$$PE = -\mu B \cos \theta$$

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

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

## Constants

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

$$1e = 1.6 \times 10^{-19} C$$

$$k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{Nm^2}{C^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{Nm^2}$$

$$1eV = 1.6 \times 10^{-19} J$$

$$\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$$

$$c = 3 \times 10^8 \frac{m}{s}$$

$$h = 6.63 \times 10^{-34} Js$$

$$m_e = 9.11 \times 10^{-31} kg = \frac{0.511 MeV}{c^2}$$

$$m_p = 1.67 \times 10^{-27} kg = \frac{937.1 MeV}{c^2}$$

$$m_n = 1.69 \times 10^{-27} kg = \frac{948.3 MeV}{c^2}$$

$$1amu = 1.66 \times 10^{-27} kg = \frac{931.5 MeV}{c^2}$$

$$N_A = 6.02 \times 10^{23}$$

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

## Electric Circuits

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

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

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

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

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

$$Q = CV = \left( \frac{\kappa \epsilon_0 A}{d} \right) V = (\kappa C_0) V$$

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

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

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

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

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

## Light as a Particle & Relativity

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

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

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

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

$$p = \gamma mv$$

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

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

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

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

## Geometry

$$\text{Circles: } C = 2\pi r = \pi D \quad A = \pi r^2$$

$$\text{Triangles: } A = \frac{1}{2}bh$$

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

## Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$S(t) = \frac{\text{energy}}{\text{time} \times \text{area}} = c\epsilon_0 E^2(t) = c \frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \frac{1}{2} c\epsilon_0 E_{max}^2 = c \frac{B_{max}^2}{2\mu_0}$$

$$P = \frac{S}{c} = \frac{\text{Force}}{\text{Area}}$$

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

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

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

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

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

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

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

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

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

## 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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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