Name______________________________________

Physics 111 Quiz #2, January 14, 2011

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

You sometimes create a spark when you touch a doorknob after shuffling your feet on a carpet. This is because the air always has a few free electrons that have been kicked out by interactions with a cosmic ray. If an electric field happens to be present, a free electron can be accelerated until it collides with an air molecule and this collision can eject another electron from that air molecule. Now instead of one free electron you have two. Each of these can go on to produce more free electrons from collisions with air molecules and what you end up with is a chain reaction of electron production in air. This is called a *breakdown of air* (and it's the basis too for a lightning strike) and the tiny burst of electrons is what gives you a shock when you touch a piece of metal. The kinetic energy of all of these moving electrons is dissipated as light (a spark) and sound (the snap of the shock.)

1. Suppose that a free electron is created with a kinetic energy of $2x10^{-18}\ J$ (which is enough to create a chain reaction of electrons in the air) and travels a distance of $2.0\mu m$ before it collides with an electron in an air molecule. What acceleration (assumed constant) would have been required for the electron to gain this kinetic energy?

a. $1.1x10^{18}\ m/s^2$

b. $2.2x10^{15}\ m/s^2$

c. $5.9x10^{14}\ m/s^2$

d. $1.2x10^{12}\ m/s^2$

$$W = \Delta KE = F\Delta x = m_e a\Delta x$$

$$\rightarrow a = \frac{\Delta KE}{m_e \Delta x} = \frac{2\times10^{-18} J}{9.11\times10^{-31} kg \times 2\times10^{-6} m} = 1.1\times10^{18}\ \tfrac{m}{s^2}$$

2 a. What electric field would have been required to produce the acceleration in question 1? (This is called the *breakdown field strength of air*.)

$$F = qE = m_e a$$

$$\rightarrow E = \frac{m_e a}{q} = \frac{9.11\times10^{-31} kg \times 1.1\times10^{18}\ \tfrac{m}{s^2}}{1.6\times10^{-19} C} = 6.3\times10^6\ \tfrac{N}{C}$$

2b. Assuming that this free electron in air is $1.0cm$ away from a point charge (say a doorknob), what minimum charge would the point charge need to have so that we can breakdown the air and cause a spark?

$$E = \frac{kq}{r^2} \rightarrow q = \frac{Er^2}{k} = \frac{6.3\times10^6\ \tfrac{N}{C} \times (0.01m)^2}{9\times10^9\ \tfrac{Nm^2}{C^2}} = 7\times10^{-8} C$$

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V}{\Delta x}$$
$$W_{A,B} = q\Delta V_{A,B}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

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

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

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

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