Name____

Physics 111 Quiz #1, January 11, 2019

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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1. Suppose that you have a proton and an electron as in a hydrogen atom, separated by a distance $d = 0.5\times10^{-10}m$. By what factor is the gravitational force of attraction between the proton and the electron smaller than the electrical force of attraction? Hint: The magnitude of the gravitational force between two objects is given by $F_G = G\frac{M_1M_2}{r_{12}^2}$, where $G = 6.67\times10^{-11}\,\frac{Nm^2}{kg^2}$.

$$\frac{F_G}{F_e} = \frac{Gm_pm_er_{pe}^2}{r_{pe}^2ke^2} = \frac{Gm_pm_e}{ke^2} = \frac{6.67\times10^{-11}\,\frac{Nm^2}{kg^2}\times1.67\times10^{-27}\,kg\times9.11\times10^{-31}\,kg}{9\times10^9\,\frac{Nm^2}{C^2}\left(1.6\times10^{-19}\,C\right)^2} = 4.4\times10^{-40}$$

2. The electron in orbit about the proton experiences a centripetal acceleration. What is the magnitude of this centripetal acceleration?

$$F_e = \frac{ke^2}{r_{pe}^2} = m_ea_e \rightarrow a_e = \frac{ke^2}{m_er_{pe}^2} = \frac{9\times10^9\,\frac{Nm^2}{C^2}\left(1.6\times10^{-19}\,C\right)^2}{9.11\times10^{-31}\,kg\left(0.5\times10^{-10}\,m\right)^2} = 1.0\times10^{23}\,\frac{m}{s^2}$$

3. How close would two protons have to be placed so that the magnitude of the electrostatic force between them is equal to the weight of either at the Earth's surface?

$$F_e = \frac{ke^2}{r_{pp}^2} = m_pg \rightarrow r_{pp} = \sqrt{\frac{ke^2}{m_pg}} = \sqrt{\frac{9\times10^9\,\frac{Nm^2}{C^2}\left(1.6\times10^{-19}\,C\right)^2}{1.67\times10^{-27}\,kg\times9.8\,\frac{m}{s^2}}} = 0.12m = 12cm$$

4. Suppose you have three point charges arranged in a horizontal line. Point charge $Q_1 = 3\mu C$ is located at $x_1 = 0m$, $Q_2 = 7\mu C$ is at $x_2 = 0.60m$, and $Q_3 = -6\mu C$ at $x_3 = 0.75m$. What is the net electrostatic force on point charge Q_1 due to point charges Q_2 and Q_3?

$$F_{net,1} = F_{13} - F_{12} = \frac{kQ_1Q_3}{r_{13}^2} - \frac{kQ_1Q_2}{r_{12}^2} = 9\times10^9 \tfrac{Nm^2}{C^2} \times 3\times10^{-6}C\left[\frac{6\times10^{-6}C}{(0.75m)^2} - \frac{7\times10^{-6}C}{(0.60m)^2}\right]$$

$$F_{net,1} = -0.24N$$

5. Alex the lightning bug has a mass m and a charge q. Samantha her lightning bug sister has a mass $\frac{3}{4}m$ and a charge $3q$. Because the charges on the lightning bugs are the same, the sisters are repelled from each other. Which is repelled more from the other and by how much?

a. Alex by three times as much.
b. Samantha by three times as much.
c. Alex by nine times as much.
d. Samantha by nine times as much.
e. They are both repelled from each other by the same amount.

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

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

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

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

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$