Name____

Physics 111 Quiz #1, September 12, 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.

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Suppose that you have the arrangement of three charges in a plane given by the following data. Charge $q_1 = -3nC$ is located at $(x,y) = (0,0)m$, charge $q_2 = 2nC$ is located at $(x,y) = (0,0.25)m$ and charge $q_3 = 2nC$ is located at $(x,y) = (0.25,0)m$.

1. What is the electric field at a point *P* in space with coordinates $(x,y) = (0.25,0.25)m$?

   A force diagram shows:

$$E_{net,x} = E_2 - E_1\cos 45 = \frac{kq_2}{r_{2p}^2} - \frac{kq_3}{r_{3p}^2}\cos 45 = 9\times 10^9 \frac{Nm^2}{C^2}\left[\frac{2\times 10^{-6}C}{(0.25m)^2} - \frac{3\times 10^{-6}C}{(2\times 0.25m)^2}\cos 45\right] = 2.1\times 10^5 \frac{N}{C}$$

$$E_{net,y} = E_3 - E_1\sin 45 = \frac{kq_2}{r_{2p}^2} - \frac{kq_3}{r_{3p}^2}\sin 45 = 9\times 10^9 \frac{Nm^2}{C^2}\left[\frac{2\times 10^{-6}C}{(0.25m)^2} - \frac{3\times 10^{-6}C}{(2\times 0.25m)^2}\sin 45\right] = 2.1\times 10^5 \frac{N}{C}$$

   The magnitude of the electric field is given by:

$$E_{net} = \sqrt{E_{net,x}^2 + E_{net,y}^2} = \sqrt{2\left(2.1\times 10^5\frac{N}{C}\right)^2} = 3\times 10^5\frac{N}{C}$$

   The direction of the electric field is given by:

$$\phi = \tan^{-1}\left(\frac{E_{net,y}}{E_{net,x}}\right) = \tan^{-1}\left(\frac{2.1\times 10^5\frac{N}{C}}{2.1\times 10^5\frac{N}{C}}\right) = 45^0$$

2. Suppose that a charge $q_4 = -3nC$ were placed at the point *P* in space with coordinates $(x,y) = (0.25,0.25)m$, what force would q_4 feel?

   The force is given by $\vec{F} = q\vec{E}$ where, $F = 3\times 10^{-6}C \times 3\times 10^5\frac{N}{C} = 0.9N$ in magnitude and at an angle of $f = 45^0 + 180^0 = 225^0$ with respect to the positive x-axis or $f = 45^0$ below the negative x-axis.

3. Suppose instead of the charges above, you instead have two protons separated by a distance d. At the midpoint along the line joining the two protons, one places a proton at rest. This proton is given a small kick perpendicular to the line joining the two protons. The resulting motion of the proton would most likely be
   a. to move away from both protons along a line perpendicular to the line joining the two protons.
   b. to oscillate about a line perpendicular to the line joining the two protons.
   c. to move towards one of the two protons depending on the direction of the initial kick.
   d. to remain at rest.
   e. unable to be determined from the information given.

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

$$g = 9.8\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\tfrac{Nm^2}{C^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\tfrac{C^2}{Nm^2}$$
$$1eV = 1.6\times10^{-19}J$$
$$\mu_o = 4\pi\times10^{-7}\tfrac{Tm}{A}$$
$$c = 3\times10^8\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}Js$$
$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2+Bx+C=0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

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

Light as a Wave

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

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$
$$KE_{max} = hf - \phi = eV_{stop}$$
$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$
$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$p = \gamma mv$$
$$E_{total} = KE + E_{rest} = \gamma mc^2$$
$$E_{total}^2 = p^2c^2 + m^2c^4$$
$$E_{rest} = mc^2$$
$$KE = (\gamma-1)mc^2$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$
$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$
$$A(t) = A_o e^{-\lambda t}$$
$$m(t) = m_o e^{-\lambda t}$$
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Geometry

Circles $C = 2\pi r = \pi D$ $\quad A = \pi r^2$

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

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

Misc. Physics 110 Formulae

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