Name_______________________________________

Physics 111 Quiz #1, September 15, 2017

*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 a square with sides of length $l = 10cm$. On the left two corners of the square there are placed $+2\mu C$ point charges while on the right two corners of the square there are placed $-2\mu C$ point charges.

1. Using a standard Cartesian coordinate system where the y-axis is vertically up and the x-axis points to the right, what is the electric field at the center of the square?

   By the symmetry in the problem, the vertical components of the electric field cancel and the horizontal components of the electric field all add since the charges have the same magnitude and they are all equally located from the midpoint. Labeling the charges clockwise starting from the upper left corner we have:

$$\sum E_x : \frac{kQ_1}{r_1^2}\cos\theta + \frac{kQ_2}{r_2^2}\cos\theta + \frac{kQ_3}{r_3^2}\cos\theta + \frac{kQ_4}{r_4^2}\cos\theta = 4\frac{kQ_1}{r^2}\cos\theta$$

$$\sum E_y : -\frac{kQ_1}{r_1^2}\cos\theta + \frac{kQ_2}{r_2^2}\cos\theta + \frac{kQ_3}{r_3^2}\cos\theta - \frac{kQ_4}{r_4^2}\cos\theta = 0$$

   The distance from each point charge to the midpoint of the square is given by the Pythagorean theorem: $r^2 = \left(\frac{L}{2}\right)^2 + \left(\frac{L}{2}\right)^2 = \frac{l^2}{2}$ and the angle $\theta$ is obtained from $\tan\theta = \frac{l/2}{l/2} = 1 \rightarrow \theta = \tan^{-1} 1 = 45^0$.
   Thus the net electric field in magnitude is
   $E_{net} = 4\frac{kQ_1}{r^2}\cos\theta = \frac{4\times 9\times 10^9 \frac{Nm^2}{C^2}\times 2\times 10^{-6}C}{\left(0.1m/2\right)^2}\cos 45 = 1.02\times 10^7 \frac{N}{C}$ and points in the positive x-direction.

2. Suppose that an electron ( $m_e = 9.11\times 10^{-31}kg$ ) could be placed at the midpoint of the square. If released from rest at the midpoint of the square, what initial acceleration would the electron feel?

   The magnitude of the initial acceleration is
   $a = \frac{F}{m} = \frac{eE}{m} = \frac{1.6\times 10^{-19}C\cdot 1.02\times 10^7 \frac{N}{C}}{9.11\times 10^{-31}kg} = 1.8\times 10^{18}\frac{m}{s^2}$.

   The direction of the initial acceleration is *opposite to the direction of the electric field*.

3. Two charges, each with charge $+Q$, are placed on a line (representing the x-axis) a distance $d$ apart. One of the charges is located $x=-\frac{d}{2}$ at while the other one is located at $x=+\frac{d}{2}$. Now suppose that one fires an electron toward the origin along the positive y-axis. The resulting motion of the electron would most likely be

a. to move away from the origin along the y-axis in the negative y-direction.
b. to oscillate above and below the x-axis along the y-axis.
c. to move towards the charge located at $x=+\frac{d}{2}$.
d. to move towards the charge located at $x=-\frac{d}{2}$.
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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

## 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 Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$

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

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

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

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

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

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

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

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

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

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

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

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

## 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

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

## Misc. Physics 110 Formulae

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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

## Geometry

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

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

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