Name_______________________________________

Physics 111 Quiz #1, September 18, 2020

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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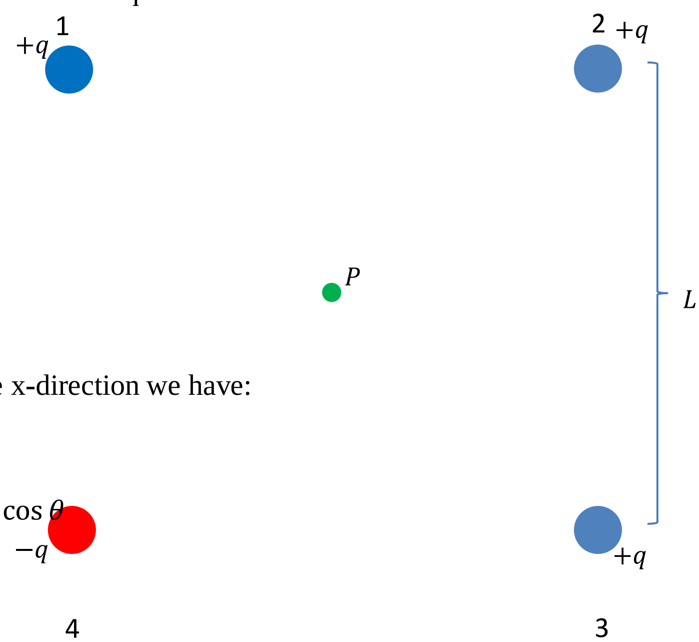
1. Suppose that you have a four, point charges located on the corners of a square with sides of length L, as shown below. The point charges each have the same magnitude of q, but the one in the lower left corner is negative, while the other three are positive. What is the x-component of the electric field at point P located at the center of the square?

   The distance between each charge and the center of the square is the same for all of the charges. This distance is given by:



$$r^2 = \left(\frac{L}{2}\right)^2 + \left(\frac{L}{2}\right)^2 = \frac{L^2}{2}$$

$$\cos\theta = \frac{L/2}{L/\sqrt{2}} = \frac{\sqrt{2}}{2} \rightarrow \theta = 45^0$$

$$\sin\theta = \frac{L/2}{L/\sqrt{2}} = \frac{\sqrt{2}}{2} \rightarrow \theta = 45^0$$

Labeling the charges as shown, we have in the x-direction we have:

$$E_{net,x} = +E_{1x} - E_{2x} - E_{3x} - E_{4x}$$

$$E_{net,x} = E_1\cos\theta - E_2\cos\theta - E_3\cos\theta - E_4\cos\theta$$

$$E_{net,x} = -2E_2\cos\theta = -2\frac{kq}{L^2/2}\cos 45$$

$$E_{net,x} = -2\sqrt{2}\frac{kq}{L^2}$$

2. What is the y-component of the electric field at point P located at the center of the square?

$$E_{net,y} = -E_{1y} - E_{2y} + E_{3y} - E_{4y}$$

$$E_{net,y} = -E_1\sin\theta - E_2\sin\theta + E_3\sin\theta - E_4\sin\theta$$

$$E_{net,y} = -2E_2\sin\theta = -2\frac{kq}{L^2/2}\sin 45$$

$$E_{net,y} = -2\sqrt{2}\frac{kq}{L^2}$$

3. What is the net electric field (magnitude and direction) at point P?

$$\left|\vec{E}_{net}\right| = \sqrt{E_{net,x}^2 + E_{net,y}^2} = \sqrt{\left(-2\sqrt{2}\frac{kq}{L^2}\right)^2 + \left(-2\sqrt{2}\frac{kq}{L^2}\right)^2} = 4\frac{kq}{L^2}$$

$$\phi = \tan^{-1}\left(\frac{E_{net,y}}{E_{net,x}}\right) = \tan^{-1}\left(\frac{-2\sqrt{2}\frac{kq}{L^2}}{-2\sqrt{2}\frac{kq}{L^2}}\right) = \tan^{-1}(1) = 45^0 \text{below the negative x-axis.}$$

4. Suppose that you placed a point charge $-q$ at point P. What would be the magnitude and direction of the net force on this point charge?

$$\vec{F} = q\vec{E} \rightarrow \left|\vec{F}_{net}\right| = \left|q\vec{E}_{net}\right| = 4\frac{kq^2}{L^2}$$

$\phi' = 45^0$above the positive x-axis since the charge is negative and feels a force opposite to the net electric field.

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

$$F = qvB\sin\theta$$

$$F = IlB\sin\theta$$

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

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

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

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

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

$$I = \frac{\Delta Q}{\Delta t}$$

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

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

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

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

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

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

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

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

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

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

Light as a Wave

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Geometry

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

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

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

Misc. Physics 110 Formulae

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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