Midterm I **Physics 51** **Spring 2012**

Last Name KEY **First Name**

1.a	1.b	1.c	1.d	2.a	2.b	3.a	3.b	3.c	4	5	Total

1. Two positive charges (q_1 and q_2), each 4.00 μC, and a negative charge, q_3 = -4.00 μC, are fixed at the vertices of a right triangle with a = 1 m as shown below. $1/4\pi\varepsilon_0 = 9\times10^9\ Nm^2/C^2$.

a. Calculate the electrical force (magnitude and direction) acting on the negative charge.

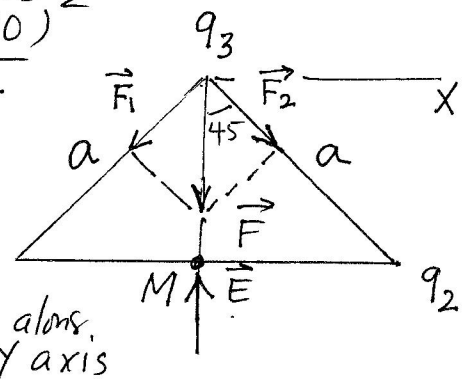
$$F_1 = F_2 = k\frac{q_3 q_1}{a^2} = k\frac{q_3 q_2}{a^2} = 9\times10^9\frac{(4\times10^{-6})^2}{1^2}$$

$$F_1 = F_2 = 0.144\ N$$

$$\vec{F} = \vec{F_1} + \vec{F_2} \qquad F_{1x} = -F_{2x},\ F_{1y} = F_{2y}$$

$$F_x = 0 \qquad F_y = 2F_{1y} = 2\times0.144\cos45$$

$$F_x = 0 \qquad F_y = 0.20\ N \qquad |\vec{F}| = 0.2 \text{ along } y \text{ axis}$$



b. Calculate the electric field (magnitude and direction) at point M shown in the figure.

$$E = \vec{E}(q_1) + \vec{E}(q_2) + \vec{E}(q_3)$$

at M $\vec{E}(q_1) + \vec{E}(q_2) = 0$ since fields due to q_1 & q_2 are in opposite directions and same magnitude.

Total $\vec{E} = \vec{E}(q_3)$ $\quad |\vec{E}| = k\frac{|q_3|}{r_M^2} = 9\times10^9 \times \frac{4\times10^{-6}}{\left(\frac{1\sqrt{2}}{2}\right)^2} = 72\times10^{+3}$ N/C $\quad r = \frac{a\sqrt{2}}{2}$

c. Calculate the electric potential at point M shown in the figure.

$$V = V_1 + V_2 + V_3 = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + k\frac{q_3}{r_3} \qquad r_1 = r_2 = r_3 = \frac{a\sqrt{2}}{2}$$

$$V = 9\times10^9\left(\frac{2\times4\times10^{-6}}{\sqrt{2}/2}\right) + 9\times10^9\left(\frac{-4\times10^{-6}}{\sqrt{2}/2}\right)$$

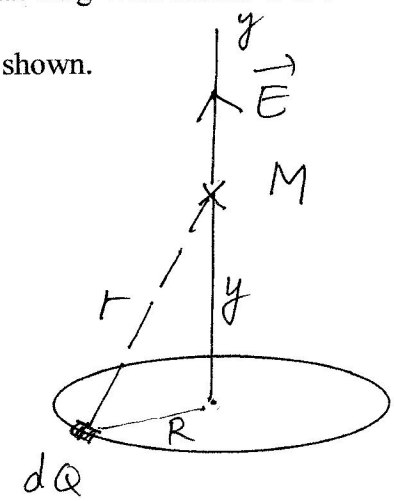
$$V = (9\times10^9)(4\times\sqrt{2}\times10^{-6}) = 5.04\times10^4 \text{ volts}$$

d. Calculate the total electric potential energy of this system.

$$U = k\frac{q_1 q_2}{r_{12}} + k\frac{q_1 q_3}{r_{13}} + k\frac{q_2 q_3}{r_{23}}$$

$$U = 9\times10^9\left\{\frac{(4\times10^{-6})^2}{\sqrt{2}} + \frac{-(4\times10^{-6})^2}{1} + \frac{-(4\times10^{-6})^2}{1}\right\}$$

2. Charge +Q is distributed uniformly over the length of a circular ring with radius a shown below.



a. Calculate the expression for the electric potential at point M shown.

$$dV = k\frac{dQ}{r} \qquad r = \sqrt{R^2+y^2}$$

$$V = \int k\frac{dQ}{\sqrt{R^2+y^2}} = \frac{k}{\sqrt{R^2+y^2}}\int dQ$$

$$V = \frac{kQ}{\sqrt{R^2+y^2}}$$

b. Use the expression for the electric potential to calculate the electric field magnitude and direction at M.

$$E_x = E_z = 0$$

$$E_y = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}\left\{\frac{kQ}{\sqrt{R^2+y^2}}\right\}$$

$$E_y = \frac{kQy}{(R^2+y^2)^{3/2}}$$

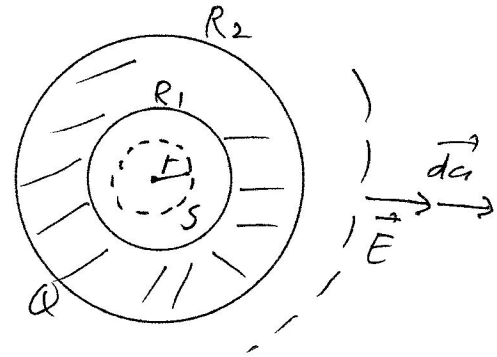
Direction along +y direction as shown

3. A Charge Q is distributed uniformly over a spherical <u>conducting</u> shell with inner radius R_1 and outer radius R_2.

a. Use Gauss' law to calculate the magnitude and direction of electric field at a point <u>inside</u> the conducting shell (distance r from the center $r<R_1$).

$E_{inside} = 0 \quad r<R_1$

Since there is no charge inside surface S shown.



b. Use Gauss' law to calculate the magnitude and direction of electric field at a point <u>outside</u> the conducting shell (distance r from the center $r>R_2$).

$$\oint \vec{E} \cdot \vec{da} = \frac{Q_{encl}}{\epsilon_0}$$

$$E \times 4\pi r^2 = \frac{Q}{\epsilon_0}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} \qquad r>R_2$$

c. What is the electric field at a point inside the conducting shell ($R_1<r<R_2$)?

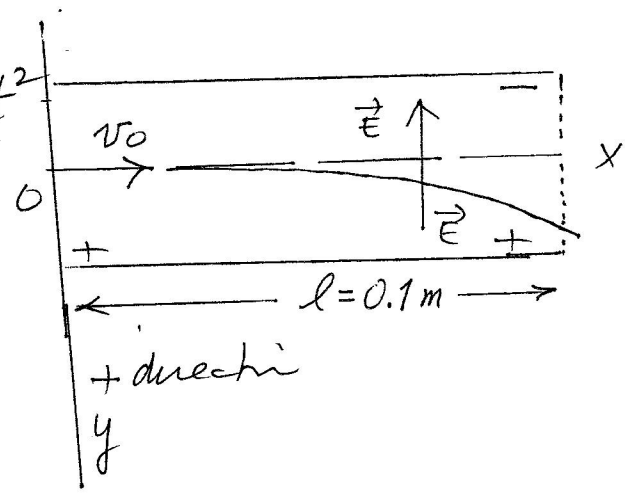
$E=0$ inside conducting material

Therefore $E=0$ for $R_1<r<R_2$

4. The constant electric field E = 300 V/m is established between two parallel plates with equal and opposite charges as shown below. An electron is released from one end of the plates with initial velocity of 300 m/sec. Calculate the deflection of the electron from its initial path when it comes out of the plate. $m_e = 9.1\times10^{-31}$ kg, $q_e = 1.6\times10^{-19}$ C. $\ell = 0.1\ m$

along x: $F_x = 0$ $a_x = 0$ $x = v_0 t$

along y $F_y = +|e|E$ $a_y = \frac{+|e|E}{m}$ $y = \frac{1}{2} a_y t^2$



$x = v_0 t$, $t = \frac{x}{v_0}$

$y = \frac{1}{2} a_y t^2 = \frac{1}{2} a_y \left(\frac{x}{v_0}\right)^2$

deflection is y and $x = \ell$

$y = \frac{1}{2} \frac{|e|E}{m} \left(\frac{\ell}{v_0}\right)^2$

$y = \frac{1}{2} \frac{(1.6\times10^{-19})(300)}{9\times10^{-31}} \left(\frac{0.1}{300}\right)^2$

6. Insert letter T (for True statement) or F (for False statement) before each statement. Correct answer 2 points, wrong answer –2 points, no answer 0 point.

a)__T__At the electric field lines and equipotential surfaces are perpendicular.

b)__F__The force acting on a positive charge in an external electric field is in the opposite direction as the electric field.

c)__T__We shoot a positive charge in a region with constant electric field in a direction perpendicular to the field. The charge will deflect from its initial path in the direction of the electric field.

d)__T__We shoot a positive charge in a region with constant electric field in a direction perpendicular to the field. The charge will have a increasing velocity in the direction perpendicular to the electric field.

e)__T__Two large parallel plates have equal and opposite charges. The electric field between the two plates is perpendicular to the plates and directs away from the plate with positive charge.

f)__T__ Positive charges are attracted toward lower potential.

g)__F__ Negative charges are accelerated toward lower potential.