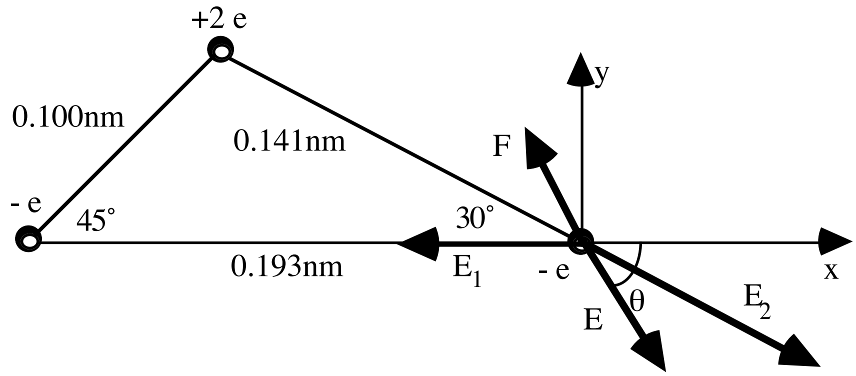
Name:____

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded. **For full credit you must explain clearly what you are doing especially if your solution involves symmetry arguments or uses Gauss's Law.**

1. At some instant the nucleus of a helium atom and its orbiting electrons are oriented as shown. Find (a)the electric field (magnitude and direction) felt by the electron at the bottom right and (b)the electric force felt by this electron.



(a)The electric fields due to the point charges are:

$$E_1 = k\frac{e}{r_1^2} = (9x10^9)\frac{1.6x10^{-19}}{(0.193x10^{-9})^2} = 3.87x10^{10} N/C$$

$$E_2 = k\frac{2e}{r_2^2} = (9x10^9)\frac{2(1.6x10^{-19})}{(0.141x10^{-9})^2} = 14.5x10^{10} N/C$$

Adding the vector components:

$$E_x = E_2\cos 30° - E_1 = 8.69x10^{10} N/C$$

$$E_y = -E_2\sin 30° = -7.25x10^{10} N/C$$

The magnitude and direction are:

$$\boxed{E = \sqrt{E_x^2 + E_y^2} = 11.3x10^{10} N/C}$$ and $$\boxed{\theta = \arctan\frac{E_y}{E_x} = -40° \text{ from the x-axis.}}$$

(b)The force on this electron can be found by the definition of electric field:

$$\boxed{\vec{E} \equiv \frac{\vec{F}}{q} \Rightarrow \vec{F} = -e\vec{E}}$$

The magnitude and direction are:

$\boxed{F = 1.81x10^{-8} N}$ and the angle is opposite $\boxed{\theta = 140° \text{ from the x-axis.}}$

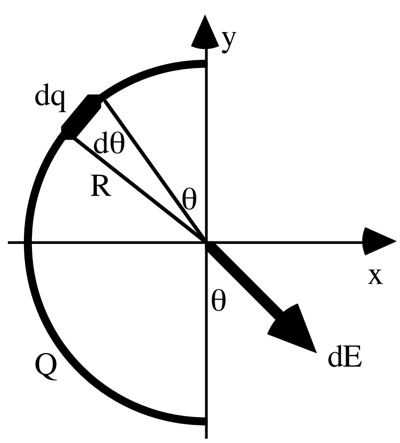
2. Consider a non-conducting cube centered at the origin. The length of each side is d and it contains a uniformly distributed charge Q throughout its volume. (a)Can you use Gauss's Law to find the total electric flux that leaves the cube? If so, find the result. If not, explain why not. (b)Can you use Gauss's Law to find the electric field at a distance d from the origin? If so, find the result. If not, explain why not.

(a)Yes! Gauss's Law states that the total flux that leaves any volume equals the enclosed charge over ε_o:

$$\boxed{\Phi = \frac{q_{encl}}{\varepsilon_o} = \frac{Q}{\varepsilon_o}}$$

(b)To use Gauss's Law to find an electric field a large degree of symmetry must exist. This problem doesn't have enough symmetry to find the field.

3. Find the electric field at the origin due to the semicircular ring of radius R and total charge Q shown.



The field due to the point charge dq is:

$$dE = k\frac{dq}{R^2}$$

Due to the symmetry of the problem, only the x-components will contribute to the answer:

$$dE_x = k\frac{dq}{R^2}\sin\theta$$

Assuming the charge is distributed uniformly,

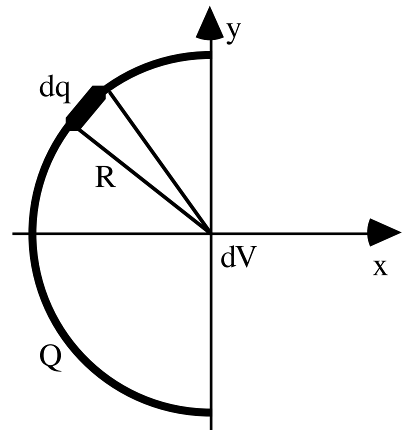
$$\frac{dq}{Q} = \frac{d\theta}{\pi} \Rightarrow dq = \frac{Q}{\pi}d\theta$$

The total field can now be found by integrating,

$$E_x = \int_0^\pi k\frac{Q}{\pi R^2}\sin\theta d\theta = k\frac{Q}{\pi R^2}\int_0^\pi \sin\theta d\theta = k\frac{Q}{\pi R^2}\left[-\cos\theta\right]_0^\pi .$$

Finally, $\boxed{E_x = 2k\frac{Q}{\pi R^2}}$

4. Find the potential at the origin due to the semicircular arc in the previous problem.



The potential due to the point charge dq is:

$$dV = k\frac{dq}{R}$$

There is no need to worry about components for potential because it isn't a vector. The total potential is,

$$V = \int k\frac{dq}{R} = k\frac{1}{R}\int dq$$

Finally, $\boxed{V = k\frac{Q}{R}}$

5. A proton is fired with $2.00\text{x}10^{-13}$J of kinetic energy toward a very distant oxygen nucleus which contains six protons. As it gets close to the nucleus it slows down and eventually comes to rest for an instant. At this instant, find (a)the potential energy of the proton, (b)the electric potential that it feels, and (c)the distance it is from the nucleus.

(a)By the Law of Conservation of Energy the kinetic energy lost by the proton must equal the potential energy it gains. Since it started a long way from the nucleus the initial potential energy is zero and the final potential energy must be $\boxed{U = 2.00\text{x}10^{-13}\text{J}}$.

(b)The potential it feels is due to the nucleus which can be found using the definition of electric potential,

$$\Delta U \equiv q\,\Delta V \Rightarrow V = \frac{U}{q} = \frac{2.00\text{x}10^{-13}\text{J}}{1.6\text{x}10^{-19}\text{C}} = \underline{\underline{1.25\text{x}10^{6}\,\text{V}}}$$

(c)This potential is created by the nucleus which can treated as a point charge,

$$V = k\frac{q}{r} \Rightarrow r = \frac{k(6e)}{V} = \frac{(9\text{x}10^{9})(6)(1.6\text{x}10^{-19})}{1.25\text{x}10^{6}} = \underline{\underline{6.91\text{x}10^{-15}\text{m}}}$$