Lab: AP Review Sheets
Chapter 5: Electric Forces and Fields

AP PHYSICS
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Background / Summary
Electric forces and fields describe the interactions between charged particles and the space around them, encompassing concepts like Coulomb's Law, electric fields, and electric potential energy.

Electric Forces
Coulomb’s Law:
- Charge of an electron is -1.602e-19C
- Charge of a proton is +1.602e-19C
- k = 9.00e9 N·m^2/C^2
- If the resulting Force is negative then the charges are attracted to each other. If the resulting Force is positive then the charges are repelling each other.
- Coulomb’s Law only applies to non-moving charges = *electrostatic situations*
- Coulomb’s Law only applies to two charges. To use it with more than two charges, the net force on any single charge will be equal to the net vector sum of the forces due to the other charges.

$$k = \frac{1}{4\pi\varepsilon_o}$$

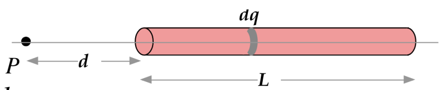
$$F_e = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}$$

Electric Fields
Electric fields are present wherever there is charge. Unlike forces, which require a secondary charge to feel their effect, electric fields exist independently. They provide information about the force available per unit charge at a given point. Therefore, the electric field is defined as follows:

$$\vec{E} = \frac{\vec{F}_E}{q}$$

Electric Field of a Charged Rod

$$dq = \lambda \; dx$$



$$\vec{\mathbf{E}} = k\int \frac{dq}{r^2}\hat{\mathbf{r}} = \; k\int \frac{dq}{x^2}$$

$$\vec{\mathbf{E}} = k\int_{d}^{d+L} \frac{dq}{x^2} = \; k\int_{d}^{d+L} \frac{\lambda}{x^2}dx$$

$$\vec{\mathbf{E}} = \; k\lambda\int_{d}^{d+L} \frac{1}{x^2}dx \; = k\lambda\left[\frac{-1}{x}\right]_{d}^{d+L} \; = \frac{kQ}{d(L+d)}$$

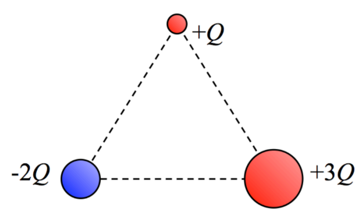
Electric Field Lines

1) The number of lines starting on a positive charge or ending on a negative charge is **proportional to the magnitude** of the charge.
2) **The closer** the lines are together in a region, **the stronger** the electric field is in that region.
3) Field lines indicate the direction of the electric field, because the **E field** at any position **points in a direction tangent to the field line** at that point.

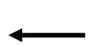
Example Problems:

Question:

1)



Three point charges, of charge $+Q$, $-2Q$, and $+3Q$, are placed equidistant as shown. Which vector best describes the net direction of the electric force acting on the $+Q$ charge?

a. 

b. 

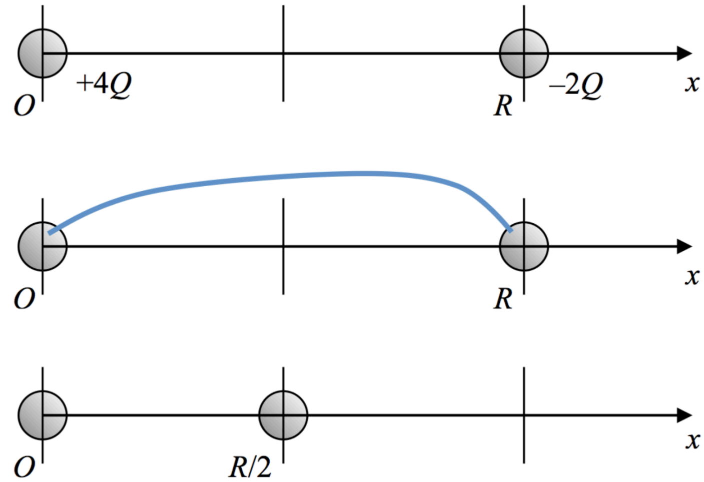
c. 

d. 

e. 

Question:

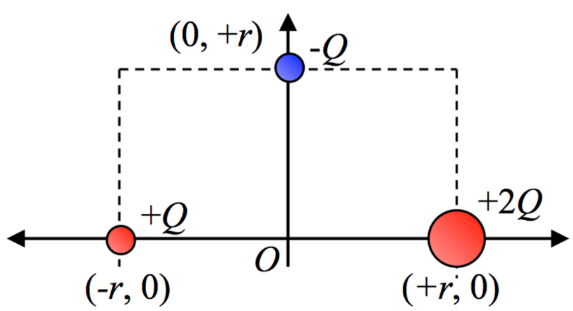
2)



Two identical, isolated conducting spheres are separated by a distance R as shown above. The sphere at the origin as a charge $+4Q$, while the other sphere at position $+R$ has a charge of $-2Q$, and the magnitude of the force between them is $\mathbf{F_0}$. The two spheres are connected to each other by a conducting wire for a moment which is then removed. When the sphere at distance R is relocated to a distance $R/2$, the vector force it experiences due to the sphere at the origin is:

Question:

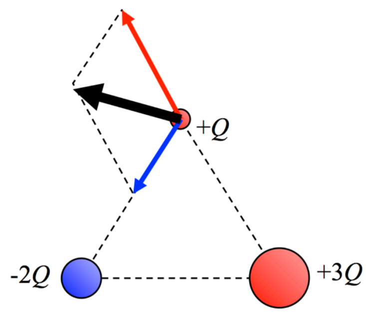
3)



Three point charges of $+Q$, $+2Q$, and $-Q$ are each located a distance r away from the origin, as shown above. The magnitude of the electric field at the origin due to these charges is:

Solutions:

Answer:
The correct answer is *b*. The direction of the electric force due to -2Q and +3Q can be visualized with a quick free-body sketch of the electric forces:

1) 

2) The original force between the spheres can be calculated using Coulomb's Law

$$F = k\frac{q_1 q_2}{r^2}$$

$$\mathbf{F_0} = k\frac{(+4Q)(-2Q)}{R^2} = -\frac{8kQ^2}{R^2}$$

When the spheres are connected, the net charge of +4Q + –2Q = +2Q is redistributed so that each sphere has +1Q. Using these new charges and the new distance between the spheres, we can calculate the new Force:

$$F' = k\frac{(+Q)(+Q)}{\left(R/2\right)^2} = +\frac{4kQ^2}{R^2}$$

$$F' = \frac{F_0}{2} \text{ in the } +x \text{ direction}$$

3) The electric field at the origin can be found by considering the sum of the electric fields of the three particles. This can be quickly determined by considering that there is an electric field in the -x direction due to a net +1Q at the (+r, 0) position, and an electric field in the +y direction due to the 1Q charge at (0, +r). Add these components together to get the answer.

$$E_{net} = \sum E_{+Q} + E_{+2Q} + E_{-Q}$$

$$E_x = +\frac{kQ}{r^2} - \frac{k2Q}{r^2} = -\frac{kQ}{r^2} \text{(in the } x\text{ - direction)}$$

$$E_y = +\frac{kQ}{r^2} \text{(in the } y\text{ - direction)}$$

$$E_{net} = \sqrt{\left(-\frac{kQ}{r^2}\right)^2 + \left(+\frac{kQ}{r^2}\right)^2} = \frac{\sqrt{2}kQ}{r^2}$$