General Physics 204, Section ... Monday, Feb 02, 2015

Quiz #1′ Coulomb's Law & Electric Field

Name:

1) CLASS(2)

Francis Hauksbee is wondering about the force between a point charge, Q, and a dipole. A dipole is a system made with two opposite charges, one positive $+q$ and one negative $-q$, sitting at a distance δ from each other. Consider a coordinate system where the charge Q is at the center. Use these numerical values,

$Q = +10\ \mu\text{C}, q = 2.0\ \mu\text{C}, r = 0.10\ \text{m}, \delta = 0.0010\ \text{m}.$

$\hat{x}$: unit vector in $+x$ direction

$\hat{y}$: " " " $+y$ "

a) We put the dipole on the x-axis, so $-q$ is at r and $+q$ is at $r+\delta$. What is the total force applied to the dipole from charge Q? Remember that force is a vector. **[3 pts]**

b) Now consider the dipole sitting on the y-axis, at a same distance r and with the same orientation, i.e. $-q$ at $(-\delta/2, r)$ and $+q$ at $(+\delta/2, r)$. Again find the total force applied on the dipole. Remember that force is a vector. **[3 pts]**

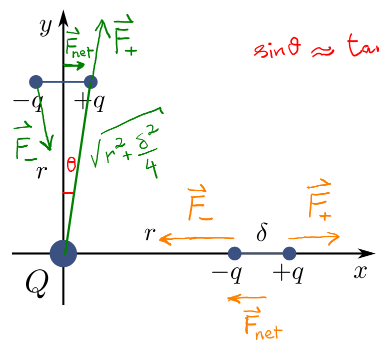

Figure 1: The interaction between a dipole and a point charge.

a) $\vec{F}_+ = k\frac{+qQ}{(r+\delta)^2}\hat{x}$

$\vec{F}_- = k\frac{-qQ}{r^2}\hat{x}$

$\vec{F}_{net} = -kqQ\hat{x}\left(\frac{1}{r^2} - \frac{1}{(r+\delta)^2}\right)$

$\approx -kQ\frac{2q\delta}{r^3}\hat{x}.$

b) $\vec{F}_+ = k\frac{qQ}{r^2+\frac{\delta^2}{4}}\left(\sin\theta\,\hat{x} + \cos\theta\,\hat{y}\right)$

$\vec{F}_- = k\frac{qQ}{r^2+\frac{\delta^2}{4}}\left(\sin\theta\,\hat{x} - \cos\theta\,\hat{y}\right)$

$\rightarrow \vec{F}_{net} = 2k\frac{qQ}{r^2+\delta^2/4}\sin\theta\,\hat{x} \approx k\frac{Qq\delta}{r^3}\hat{x}.$

In $\hat{y}$ direction $\vec{F}_+$ and $\vec{F}_-$ cancel each other out. But in $\hat{x}$ direction they add up.

2) CLASS(2)

An electron starts moving inside a parallel plate capacitor with an electric field $\mathbf{E} = -\hat{\mathbf{x}}1.0 \times 10^4$ N/m. See fig. 2. Initially the electron is at rest. The distance between the plates are $d = 2.0$ cm. Take the mass of the electron to be $m_e = 9.1 \times 10^{-31}$ kg and its charge to be 1.6×10^{-19} C.

$\hat{x}$: unit vector in $+x$ direction

a) How long it takes for the electron to reach the positive plate? **[2 pts]**

b) How fast the electron moving when reaches the positive plate? **[2 pts]**

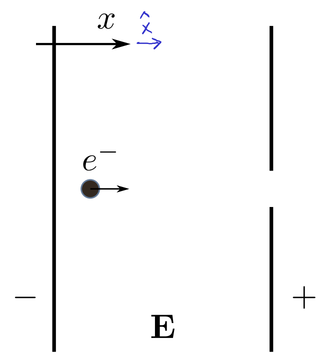

Figure 2: Electron accelerating by electric field.

a) $\vec{F} = -e\vec{E} = m_e\vec{a} \rightarrow \vec{a} = \hat{x}\frac{eE}{m_e}$

$= \hat{x}\,1.8\times10^{15}\ \frac{m}{s}$

e^- interacts w/ electric field

Newton's 2nd law (Dynamics)

Kinematics (const. acceleration)

$x(t) = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 = \frac{1}{2}\frac{eE}{m_e}t^2$ (with $x_0 = 0$, $v_{0x} = 0$)

$x(t^*) = d \rightarrow t^* = \left(\frac{2m_e d}{eE}\right)^{1/2} = 4.7$ ns

b) $v_x(t) = v_{0x} + a_x t \rightarrow v_x(t^*) = \left(\frac{2eEd}{m_e}\right)^{1/2} = 8.5\times10^6\ \frac{m}{s}.$

Kinematics (const. acceleration)