Quiz 1 – Electrostatics (17 Jan 2007)

The force on charge q_1 from charge q_2 is $\vec{F}_{12} = k_e \frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$, where the direction vector $\hat{r}_{12}$ points from q_2 to q_1 and the proportionality constant is $k_e = 8.99 \times 10^9$ Nm^2/C^2.

Note that the permittivity of free space is $\varepsilon_0 \equiv \frac{1}{4\pi k_e} = 8.85 \times 10^{-12}$ C^2/(Nm^2).

Note that the unit of elemental electronic change is $e^- = -1.62 \times 10^{-19}$C.

We note the Taylor's expansion $(1+x)^n = 1 + nx + \cdots$, which is useful when nx << 1. For example,

$$\frac{1}{(r+d)^2} = \frac{1}{r^2}\left(1+\frac{d}{r}\right)^{-2} = \frac{1}{r^2}\left(1 - 2\frac{d}{r} + \cdots\right) \simeq \frac{1}{r^2} - 2\frac{d}{r^3} \text{ for d << r.}$$

The force on a test charge q_0 induced by an electric field, denoted $\vec{E}$, is $\vec{F} = q_0\vec{E}$.

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1. Two positive charges of strength $Q_1 = +1.0 \times 10^{-3}$ Coulombs sit along the x-axis as shown in figure 1 ($+\hat{x}$ points to the right along x & $+\hat{y}$ points to the up along y), with L = 20 cm. What is the x-direction of the force on a negative charge of strength $Q_2 = -1.0 \times 10^{-6}$ Coulombs that sits at (x, y) = (L, L)?

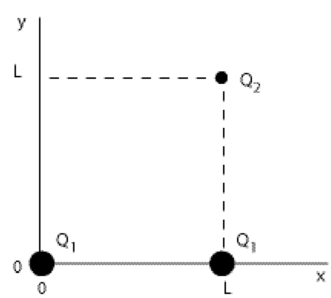

Figure 1

A) -3.0×10^2 N $\hat{x}$
B) -2.3×10^3 N $\hat{x}$
C) -7.9×10^1 N $\hat{x}$
D) $+3.0 \times 10^2$ N $\hat{x}$
E) $+7.9 \times 10^1$ N $\hat{x}$

2. With reference again to figure 1, and Q_1, Q_2, and L defined as above, what is the y-direction of the force on Q_2?

A) -3.0×10^2 N $\hat{y}$
B) -2.3×10^2 N $\hat{y}$
C) -7.9×10^1 N $\hat{y}$
D) -6.1×10^1 N $\hat{y}$
E) -3.0×10^0 N $\hat{y}$

3. Two charged balls with identical mass, M, form a double pendulum as shown in figure 2. The charge on one ball is $Q_1 = +1.0\text{x}10^{-6}$ C and the other is $Q_2 = +3.0\text{x}10^{-6}$ C. The strings have the same length, with L = 20 cm and the angle formed by the two balls is $2\theta = 60^0$ ($\theta = 30^0$). What is the mass?

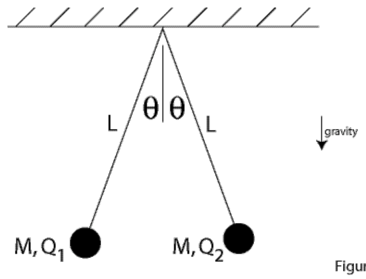

Figure 2

A) 3.0 x 10^{-2} kg
B) 1.2 x 10^{-1} kg
C) 4.8 x 10^{-1} kg
D) 1.2 kg
E) This system is unstable as the two values of the charge are different.

4. Four charges, two positive with strength +|e| and two negative with strength –|e|, are *symmetrically* configured along the **x**-axis as shown in figure 3. What is the force on the test charge q_o?

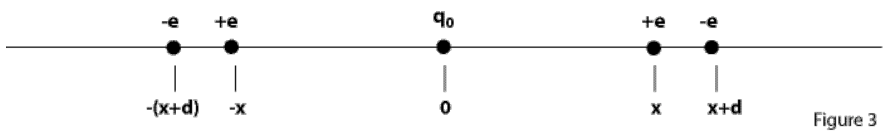

Figure 3

A) $k_e \dfrac{q_o e d}{r^3}\hat{x}$

B) $k_e\left(\dfrac{q_o e}{r^2} - \dfrac{q_o e}{(r+d)^2}\right)\hat{x}$

C) $k_e \dfrac{q_o e d}{8r^3}\hat{x}$

D) zero

E) $k_e\left(\dfrac{2q_o e}{r^2} - \dfrac{2q_o e}{(r+d)^2}\right)\hat{x}$

5. A charged sphere with mass M = 1.0 x10^{-15} kg and unknown charge Q is suspended in a uniform electric field of 1.0 x10^7 N/C, as shown in figure 4. Recall that the gravitational acceleration is 9.8 m/s^2 and that 1 N = 1 kg m/s^2. What is the strength of the charge (sign and magnitude of Q) that is required to suspend the particle?

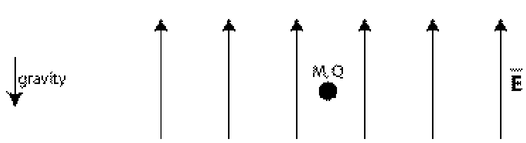

Figure 4

A) + 8.8x10^{-12} C
B) +9.8 x 10^{-22} C
C) +9.8 x 10^{-25} C
D) -9.8 x 10^{-25} C
E) -9.8 x 10^{-22} C