Quiz 2 solutions

April 25, 2012

Figure 1

Figure 2

1. (See figure 1.) Consider a solution of sodium hydroxide (NaOH). We model an OH- radical as an oxygen with -2 electrons charge, connected to a hydrogen with +1 proton charge. A dissociated sodium ion, Na+, the O(-2), and H+ are in a straight line, in that order. The Na+ ion is 8.0e-10 m from the O(-2), and the O(-2) is 1.0e-10 m from the H+. What is the net force on the Na+ from the OH-, in N?
none of these

$$k_e \frac{-2 \times 1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C}{(8.0 \times 10^{-10} m)^2} + k_e \frac{1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C}{(9.0 \times 10^{-10} m)^2} = -4.4 \times 10^{-10} N$$

So the magnitude of the total electric force should be $4.4 \times 10^{-10} N$.
2. A defibrillator stores energy on a 30. micro-F capacitor. To store 3.0e2 J of energy, to what voltage must it be charged, in V?
4,500
We have

$$U = \frac{1}{2} C (\Delta V)^2.$$

So

$$\Delta V = \sqrt{\frac{2U}{C}} = \sqrt{\frac{2 \times 300 J}{30 \times 10^{-6} F}} = 4472.1 V$$

3. A 2.5 m conducting rod is immersed in an electric field directed along its length. The field strength is 20. N/C. What is the voltage difference between the ends of the rod, in V?

0
Every point on the surface and in a charged conductor in electrostatic equilibrium is at the same potential.
4. A 30. micro-F capacitor is charged to 60 V. What is the E-field between its plates, in N/C?
not enough information
We can get total charge Q, but we still need to know the area of the plates A or the separation of the plates d to calculate the E-field.
5. (See figure 2.) A bound NaOH molecule is modeled as Na+ bound to O(-2) bound to H+, in a straight line in that order. The Na+ ion is 1.0e-10 m from the O(-2), which is 1.0e-10 m from the H+. How much energy does it take to remove the Na+ ion from the molecule (i.e., take it to far away), in J?
The initial total electric potential energy is:

$$U_i = k_e \frac{-2 \times 1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C}{10^{-10} m} + k_e \frac{1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C}{2.0 \times 10^{-10} m} = -3.5 \times 10^{-18} J$$

To take them far apart, which means the final total electric potential energy U_f is zero, we need to do work $W = 3.5 \times 10^{-18} J$. It is from the energy conservation(The work you do to separate them transforms into electric potential energy):

$$U_i + W = U_f$$

6. A 0.0090 kg ball is placed in a downward E-field of 4.0e4 N/C. A charge on the ball keeps it stationary against gravity. What is the charge, in C?
-2.2e-6
Let's define upward as $\hat{z}$, so E-field $\vec{E} = E(-\hat{z})$. The charge is stationary means the total force is zero:

$$F_e \hat{z} + mg(-\hat{z}) = 0,$$

which means

$$E(-\hat{z})q = F_e \hat{z} = mg\hat{z}$$

so

$$q = \frac{mg}{-E} = \frac{0.0090 kg \times 9.8 m/s^2}{-4 \times 10^4 N/C} = -2.2 \times 10^{-6} C$$

7. An electron in a picture tube starts at rest. It is accelerated by 25,000 V across a distance of 0.50 m to the screen. What is its energy when it hits the screen, in J?
4.0e-15

$$\Delta KE = |\Delta U| = |q\Delta V| = 1.6 \times 10^{-19} \times 25000V = 4.0e - 15J$$

8. A capacitor has plates of area 2.0e-4 m^2, spaced 0.10 mm apart. It is charged to 5.0 V. What is the magnitude of the E-field between its plates, in N/C?
5.0e4

$$E = \frac{\Delta V}{d} = \frac{5V}{0.1 \times 10^{-3}m} = 5 \times 10^4 N/C$$

9. q_1 is 2 C; q_2 is -4 C. They are spaced so that q_1 pulls on q_2 with 2.5 N. What is the force of q_2 on q_1?
pulls with 2.5 N
Because two charges have different signs, they pull each other with same amount of force.

$$\vec{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{r}_{12} = -2.5N \hat{r}_{12}$$

$$\vec{F}_{21} = k_e \frac{q_1 q_2}{r^2} \hat{r}_{21} = -2.5N \hat{r}_{21}$$

Actually you can get the same answer just through Newton's 3rd Law.
10. An electron in a picture tube starts at rest. It is accelerated by 25,000 V across a distance of 0.50 m to the screen. How long does it take to travel to the screen, in s?
1.1e-8
Because the electron starts at rest, so we have

$$d = 0.5m = \frac{1}{2} a t^2,$$

where a is the acceleration due to the electric force $F_e = Eq = m_e a$, so

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2d}{Eq/m_e}},$$

and we can get E from $E = \Delta V/d$, so

$$t = \sqrt{\frac{2d \times d \times m_e}{\Delta V q}} = \sqrt{\frac{2 \times 0.5m \times 0.5m \times 9.1 \times 10^{-31} kg}{25000V \times 1.6 \times 10^{-19} C}} = 1.1 \times 10^{-8} s$$