Chapter 10 Problems

Physics with Health Science Applications

Section 10.1 Pg. 283

10.1. (I) How many excess electrons does an object with a total charge of -1.0 x 10^{-9} Coulombs have on it? This is approximately the amount of charge involved in commonly encountered static electricity.

The charge on one electron is -1.6 x 10^{-19} Coulombs.

We can approach this as a unit conversion problem.

$$\textbf{\textit{Ans.}}\quad -1.0x10^{-9}C\bullet\frac{1\text{ electron}}{-1.6x10^{-19}C}=6.25x10^{9}\,electrons$$

10.2. (I) How many electrons must be removed from an object to leave it with a charge of 2.0 x 10^{-10} C? This is a fairly small, though not negligible, static charge.

We can approach this as a unit conversion problem.

$$\textbf{\textit{Ans.}}\quad 2x10^{-10}C\bullet\left(\frac{1electron}{1.6x10^{-19}C}\right)=1.25x10^{9}\,electrons$$

10.3. (I) (a) Calculate the force between two identical charges of 1.0 x 10^{-9} C separated by 1.0 cm. These charges are typical of those involved in static electricity. (b_1) What is the force if the separation is doubled? (b_2) tripled? (c) What is the force if the charges are increased by a factor of 10 and the separation is kept at 1. 0 cm?

We will Coulombs law for the electric force on a stationary, charged object.

a) $$\textbf{\textit{Ans.}}\quad F_E=k\frac{q_1q_2}{d^2}=9x10^9\bullet\frac{1.00x10^{-9}C\bullet1.00x10^{-9}C}{(0.01m)^2}=9.0x10^{-5}\,Newtons$$

b_1) ***Ans.*** Because of the inverse square relationship between the force and distance, if separation is doubled, the new force will be 1/4 of the original force.

$$F'=\frac{F}{2^2}=\frac{9.0x10^{-5}N}{4}=2.25x10^{-5}N$$

b_2) ***Ans.*** Because of the inverse square relationship between the force and distance, if separation is tripled, the new force will be 1/9 of the original value.

$$F'=\frac{F}{3^2}=\frac{9.0x10^{-5}N}{9}=1.0x10^{-5}N$$

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10.3. continued

c) ***Ans.*** Because the force is directly proportional to the charges, if each charge is increased by a factor of 10, the force will be 100 times the original value.

$$F' = F \bullet 10 \bullet 10 = 9.0x10^{-5} N \bullet 100 = 9.0x10^{-3} N$$

10.7. (1) The energy expended by a battery is related to both battery voltage and the amount of charge it moves. (a) Calculate the energy in joules put out by a 9.0 V calculator battery that moves 3.0 C of charge through a handheld calculator after 1 hr of operation. (b) Calculate the energy put out by a 12.0 V car battery that moves 1000 C of charge (as it may when starting the car's engine).

We will solve the definition of Voltage for energy.

$$Voltage \equiv \frac{Energy}{charge} \quad \text{Therefore,} \quad Energy = Voltage \bullet \text{charge}$$

Ans.

a) $Energy = Voltage \bullet \text{charge} = 9 \frac{joules}{C} \bullet 3C = 27$ joules of energy

b) $Energy = Voltage \bullet \text{charge} = 12 \frac{joules}{C} \bullet 1000C = 12{,}000$ joules of energy

c) $Energy = Voltage \bullet \text{charge} = 20{,}000 \frac{joules}{C} \bullet 5x10^{-4} C = 10$ joules of energy

10.8. (I) About 20,000 V is required to create a spark 1.0 cm long through dry air. If you walk across a rug and a spark 1. 0 cm long jumps between your finger and a doorknob, how much energy is released in the spark given that 5.0 x 10^{-9} C of charge flows?

We will solve the definition of Voltage for energy.

$$Voltage \equiv \frac{Energy}{charge} \quad \text{Therefore,} \quad Energy = Voltage \bullet \text{charge}$$

$$Energy = Vq = 20{,}000 \frac{j}{C} \bullet 5x10^{-9} C = 1.0x10^{-4}\ joules$$

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10.9. (III) (a) Calculate the speed of an electron accelerated by a voltage of 12,000 V in the CRT of a black and white TV. (b) Compare this with the speed obtained in the CRT of a color TV that uses 25,000 V to accelerate electrons. The mass of an electron is $9.11x10^{31}\,kg$.

a) ***Baby step 1***. The electrical potential Energy of the electron can be calculated from the definition of voltage.

$Voltage \equiv \dfrac{Energy}{charge}$ Therefore, $Energy = Voltage$•charge

Baby step 2. From conservation of energy we know that the electrical potential energy of the electron when it is next to the negative plate, will equal its kinetic energy as it strikes the positive plate.

Recall that definition of kinetic energy: $K.E. \equiv \dfrac{1}{2}mv^2$

Baby step 3. We set the electrical potential energy equal to the kinetic energy. Elec. Pot. E = K.E.

$$Vq = \frac{1}{2}mv^2$$

Baby Step 4. Solve for the velocity, v, of the electron.

$$v = \sqrt{\frac{2Vq}{m}} = \sqrt{\frac{2 \bullet 12{,}000\,\frac{j}{C} \bullet 1.6x10^{-19}\,C}{9.11x10^{-31}\,kg}}$$

Ans. $v = 6.49x10^7\,\dfrac{m}{s}$

b) Given an electrical potential difference of 25,000 Volts, repeat baby steps 1-3 and then substitute the new voltage.

$$v = \sqrt{\frac{2Vq}{m}} = \sqrt{\frac{2 \bullet 25{,}000\,\frac{j}{C} \bullet 1.6x10^{-19}\,C}{9.11x10^{-31}\,kg}}$$

Ans. v = 9.37 x 10^7 m/s

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10.12. (I) Sparks between charged objects, such as between hair and a comb on a dry day, can move a charge of about 2.0 x 10^{-9} C. The spark may last only about $1\mu Sec$.

What current in a) amperes and b) milliamps flows under these circumstances?

We will use the definition of current: $I \equiv \frac{q}{t}$. Also recall that 1μ equals 1 x 10^{-6}.

Ans. a) $I \equiv \frac{q}{t} = \frac{2.0x10^{-9}C}{1x10^{-6}\,\text{sec}} = 2.0x10^{-3}amps$

Ans. b) $2x10^{-3}amps\frac{1000milliamps}{1amp} = 2.0milliamps$

10.13. (I) A heart defibrillator can sometimes restore a normal heartbeat to a heart attack victim. Suppose the defibrillator passes 6 A of current through the heart for 0.01 sec. <u>How much charge</u> passes through the heart in this event? (The total current and charge passing through the torso are larger. See Table 10.1.)

The definition of current is: $I \equiv \frac{q}{t}$

Solving for charge yields, and substituting values yields,

Ans. $q = I \bullet t = 6\frac{C}{\text{sec}} \bullet 0.01\,\text{sec} = 0.06$ Coulombs