Name ____

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Quiz 2

Useful Things

$$\vec{\mathbf{F}}_{e,12} = k_e \frac{q_1 q_2}{r_{12}^2}\,\hat{\mathbf{r}} \qquad \vec{\mathbf{F}}_{\text{net}} = m\vec{\mathbf{a}}$$

$$\Delta V = IR = [\text{Volts}] \qquad v_d = \frac{-e\tau}{m_e}E = [\text{m/s}]$$

$$I = \frac{\Delta Q}{\Delta t} = [\text{Amps}] \qquad I = nqAv_d = \frac{\Delta V}{R}$$

1. A "free" electron and a "free" proton are placed in an identical electric field. Which of the following statements are true? *Check all that apply.* Note that the electron mass is 9.11×10^{-31} kg, and the proton mass is 1.67×10^{-27} kg.

- □ Each particle is acted on by the same electric force and has the same acceleration.
- □ The electric force on the proton is greater in magnitude than the force on the electron, but in the opposite direction.
- ■ The electric force on the proton is equal in magnitude to the force on the electron, but in the opposite direction.
- ■ The magnitude of the acceleration of the electron is greater than that of the proton.
- □ Both particles have the same acceleration.

The electric force is the same in magnitude because both the proton and electron have the same magnitude of charge. Since they have different signs, though, the forces are in opposite directions. For the same force, the electron experiences a larger acceleration because it is much lighter than the proton.

2. Two isolated identical conducting spheres have a charge of q and $-3q$, respectively. They are connected by a conducting wire, and after equilibrium is reached, the wire is removed (such that both spheres are again isolated). What is the charge on each sphere?

- □ q, $-3q$
- ■ $-q$, $-q$
- □ 0, $-2q$
- □ $2q$, $-2q$

When we connect the spheres, since everything is conducting the charges spread out evenly over both spheres. The total charge is $q+(-q)=-2q$, spread out evenly over both spheres, which gives $-q$ on each.

3. When we power a light bulb, are we using up charges and converting them to light?

- □ Yes, moving charges produce "friction" which heats up the filament and produces light
- □ Yes, charges are emitted and observed as light
- □ No, charge is conserved. It is simply converted to another form such as heat and light.
- ■ No, charge is conserved. Moving charges produce "friction" which heats up the filament and produces light.

No, charge is conserved. Charges moving through the filament produce "friction" which heats up the filament and produces light.

Charges are not used up, and charge cannot be converted to heat or light. The "friction" charges experience is resistance, which leads to a conversion of the charges' electrical potential energy into vibrational energy in the wire (heat) through collisions between the charges and atoms in the wire. The filament heats up due to the collisions between the charges and its atoms, and glows at it gets hotter.

Name

4. In semiconductors such as Si, the number of carriers is not fixed, it depends on *e.g.,* temperature. For a certain sample of Si, the number of carriers doubles but their drift velocity decreases by 10 times. By how much does the sample's resistance change?

- □ 2 times lower
- □ 5 times lower
- ■ 5 times higher
- □ 2 times higher

This is easily answered with some algebra. First, we recall the relation between *current* and drift velocity:

$$I = nqAv_d$$

What we are really after is the resistance, however, which we can find with Ohm's law:

$$R = \frac{\Delta V}{I} = \frac{\Delta V}{nqAv_d} \propto \frac{1}{nv_d}$$

So the resistance is inversely proportional to the carrier density and drift velocity. Let's say the initial resistance is R_0, and the resistance after changing n and v_d is just R. If we double the number of carriers, the resistance goes *down* by a factor of two. If we decrease the drift velocity by 10 times, the resistance goes *up* by 10 times.

$$\begin{aligned} R_o &\propto \frac{1}{nv_d} \\ R &\propto \frac{1}{(2n)\left(\frac{v_d}{10}\right)} = \frac{10}{2nv_d} = \frac{5}{nv_d} \\ \implies R &= 5R_o \end{aligned}$$

Even though we don't know what the actual resistance R_0 is, we can say that R is five times more after the carrier concentration and velocity change. The one tricky step here is to write down the proper relationship between *resistance* and the given quantities, not just the relationship between *current* and the given quantities.

5. An electric current of 1 mA flows through a conductor, which results in a 150 mV potential difference. The resistance of the conductor is:

- ■ $150\,\Omega$
- □ $6.7 \times 10^{-4}\,\Omega$
- □ $1.5 \times 10^{-6}\,\Omega$
- □ $6.7\,\Omega$

This is just plugging the numbers straight in to Ohm's law:

$$R = \frac{\Delta V}{I} = \frac{150\,\text{mV}}{1\,\text{mA}} = \frac{150 \times 10^{-3}\,\text{V}}{1 \times 10^{-3}\,\text{A}} = 150\,\text{V/A} = 150\,\Omega$$