Name ______________________________ Date ____________

# PH 102 Quiz 4: Solution

$$\Delta V = IR \qquad I = v_d n q A \qquad R = \frac{\varrho l}{A}$$

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

○ Yes, charges moving through the filament 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. 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.

2. The drift velocity of charges in a typical copper wire is very small, $\sim 10^{-3}$ m/s. At this rate, it would take about 15 minutes after flipping the switch for your lights to come on. Why do your lights actually come on almost instantaneously?

⊗ Charges are already in the wire. When the circuit is completed, there is a rapid rearrangement of surface charges in the circuit.

○ Charges store energy. When the circuit is completed, the energy is released.

○ Charges in the wire travel very fast

○ The circuits in a home are wired in parallel. Thus, a current is already flowing

This one can be solved by elimination if nothing else. Clearly, the charges in the wire are not traveling very fast, the problem states this. That takes out the third answer. Wiring the house in parallel does not make a difference – there is no current flowing through the light bulb when the switch is off no matter how the house is wired. If there were a current already, the light would be on! If this were true, what good would the switch be? There can be a current flowing in adjacent circuits, but this is not relevant for the bulb itself. This takes out the fourth answer.

Charges do not store energy just sitting in a wire, their energy only changes by moving between regions of differing electrical potential. Electrical potential energy is also not ‘released’ by the charges. Once a current flows, the charges collide with the atoms and the electrical potential energy is converted to vibrational energy of the atoms in the wire. This process requires a current to flow, so we still have to reconcile the tiny drift velocity with the almost instantaneous action of the light switch. Electrical potential energy cannot just magically be converted to light. This would be the same as saying that gravitational potential energy could just be released by an object. How? And released to where? The second answer, though it seems halfway reasonable at first, is just using a bunch of words that sound right in a non-meaningful way.

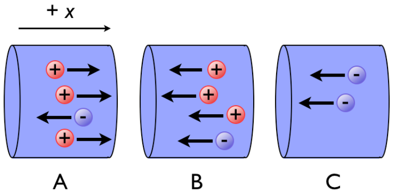
The real answer is that the wire is already full of charges. Turning on the light switch pushes charges in one end of the wire, and this displaces the charges already in the wire all along its length. The charges on the far end of the wire are pushed out as a result, and this is how current flows almost instantaneously – even though a single charge moves slowly, each charge pushes its neighbor further down the wire, and the *net* movement of charge occurs rapidly across the wire.

It is the same as turning on the hot water faucet in a way. Water comes out right away – the pipe is already filled with water. *Hot* water only comes out after some time, since it takes a while for water to go from the water heater to the faucet. Charges come out of the wire right away, but they are not the same charges entering the other end of the wire – the wire is already full of charge.

3. If you double the current through a resistor ...

⊗ The potential difference doubles
○ The potential difference is half
○ The potential difference is the same
○ None of the above

Since $I = \Delta V/R$, if $I$ doubles and $R$ remains the same, $\Delta V$ must also double.



4. Rank the relative currents in figures a, b, and c from lowest to highest. Assume positive current corresponds to positive charges flowing to the right, and that all charges move at the same velocity.

○ $a < b < c$
○ $b < a < c$
○ $c < b = a$
⊗ $b < c < a$

If all charges move at the same velocity, we can just add up the net movement of charge, since they all cover the same distance in the same amount of time. Remember that a negative charge moving forward is the same as a positive charge moving backward, and *vice versa*.

In a, we have 3 positive charges moving to the right giving a $+3$ contribution to the current, and a negative charge moving left that gives another $+1$ for a total of $+4$.

In b, we have three positive charges moving left, giving a $-3$ contribution, and one negative charge moving left, for a $+1$ contribution, or $-2$ in total.

In c, we have two negative charges moving left, giving a $+2$ contribution. The current in a is the highest, followed by c, and b is the lowest.

5. Suppose a current-carrying wire has a cross-sectional area that gradually becomes smaller along the wire, so that the wire has the shape of a very long cone. How does the drift speed vary along the wire? *Hint - perhaps an equation above can help.*

○ It slows down as the cross section becomes smaller
⊗ It speeds up as the cross section becomes smaller
○ It doesn't change
○ More information is required

From the equation above, we can relate current, area, and drift velocity:

$$I = v_d n q A \qquad \text{or} \qquad v_d = \frac{I}{nqA}$$

This tells us that drift velocity scales inversely with the area, so if the area *decreases*, the drift velocity must *increase*. Again, it works the same way for water in pipes – the smaller the pipe, the higher the pressure and the larger the velocity.