St John Baptist De La Salle Catholic School, Addis Ababa

Grade 10 Physics Midterm Review Questions and Solutions
3rd Quarter

March, 2022

No notes, or other aids are allowed. Read all directions carefully and write your answers in the space provided. To receive full credit, you must show all of your work. **You can use a calculator.**

Name:______________________________ Roll Number:______

1. Which of the following is true about resistance?
   A. Temperature has a negative correlation with resistance
   B. Metallic conductors have no resistance.
   C. The resistance of two resistors is greater when they are connected in series.(**Correct Answer**)
   D. The resistivity of conductors is greater than the resistivity of insulators.

2. (2 points) Consider a capacitor in a circuit, how do expect the capacitor to impact physical quantities?
   A. The capacitor acts a conducting wire and does not impact the circuit in any way whatsoever.
   B. The energy dissipated in the circuit due to the capacitor will be $E = QV$.
   C. The capacitor acts as a source of potential difference when the circuit is broken or the battery runs out of power.(**Correct Answer**)
   D. Resistors can be used as capacitors if connected in parallel to the potential difference source.

3. (2 points) If there are Avogadro's number of electrons in a circuit and the potential difference across the plates of the capacitor in the circuit is 220V, what should the capacitance of the capacitor be?
   A. 6.022μF
   B. 96354.25 μC
   C. 0.438kF(**Correct Answer**)
   D. 437.9μC

4. (2 points) The conductivity of a material is a physical quantity determined by computing the reciprocal of the resistivity of a substance, that is, Conductivity $= \frac{1}{\rho}$. What is the dimensional expression of the conductivity of a material?
   A. $[M^{-1}L^{-3}T^{3}A^{2}]$(**Correct Answer**)
   B. $[ML^{-3}T^{-3}A^{-2}]$
   C. $[MLT^{-3}A^{-2}]$
   D. None of the above

5. (2 points) Which of the following is true about capacitance and resistance?
   A. The same factors that affect capacitance affect resistance - the same way.
   B. Capacitance and resistance are inversely proportional.
   C. Areal increase in wires contributes positively for capacitors while negatively impacting resistance(**Correct Answer**)
   D. A resistor can replace a capacitor in a circuit and function the same way.

6. (2 points) A heart defibrillator is used to resuscitate an accident victim by discharging a capacitor through the trunk of her body. A simplified version of the circuit is seen in the figure below. (a) What is the time constant if an $\mathbf{8.00\text{–}\ \mu F}$ capacitor is used and the path resistance through her body is $\mathbf{1.00 \times 10^{3}\ \Omega}$? (b) If the initial voltage is 10.0 kV, how long does it take to decline to $\mathbf{5.00 \times 10^{2}\ V}$?
   Solution: Solution for (a)

   The time constant $\boldsymbol{\tau}$ is given by the equation $\boldsymbol{\tau = RC}$. Entering the given values for resistance and capacitance (and remembering that units for a farad can be expressed as $\mathbf{s/\Omega}$) gives

   $\boldsymbol{\tau = RC = (1.00 \times 10^{3}\ \Omega)(8.00\ \mu F) = 8.00\ ms}$.

   Solution for (b)

   In the first 8.00 ms, the voltage (10.0 kV) declines to 0.368 of its initial value. That is:

   $\boldsymbol{V = 0.368 V_0 = 3.680 \times 10^{3}\ V\ \text{at}\ t = 8.00\ ms}$. (Notice that we carry an extra digit for each intermediate calculation.) After another 8.00 ms, we multiply by 0.368 again, and the voltage is

$$\boldsymbol{V'} = \mathbf{0.368\ V}$$

$$= \mathbf{(0.368)\ (3.680 \times 10^3\ V)}$$

$$= \mathbf{1.354 \times 10^3\ V\ at\ \boldsymbol{t} = 16.0\ ms}.$$

Similarly, after another 8.00 ms, the voltage is

$$\boldsymbol{V''} = \mathbf{0.368}\boldsymbol{V'} = \mathbf{(0.368)(1.354 \times 10^3\ V)}$$

$$= \mathbf{498\ V\ at\ \boldsymbol{t} = 24.0\ ms}.$$

Discussion

So after only 24.0 ms, the voltage is down to 498 V, or 4.98 percent of its original value. Such brief times are useful in heart defibrillation, because the brief but intense current causes a brief but effective contraction of the heart.

7. (2 points) A car headlight filament is made of tungsten and has a cold resistance of $\mathbf{0.350\ \Omega}$. If the filament is a cylinder 4.00 cm long (it may be coiled to save space), what is its diameter?(The resistivity of tungsten is given in the solution)

Solution:

The cross-sectional area, found by rearranging the expression for the resistance of a cylinder given in $\boldsymbol{R} = \frac{\boldsymbol{\rho L}}{\boldsymbol{A}}$, is

$\boldsymbol{A} = \frac{\boldsymbol{\rho L}}{\boldsymbol{R}}$ Substituting the given values, and taking $\boldsymbol{\rho}$, yields

$$\boldsymbol{A} = \frac{\mathbf{(5.6 \times 10^{-8}\ \Omega \cdot m)(4.00 \times 10^{-2}\ m)}}{\mathbf{0.350\ \Omega}}$$

$$= \mathbf{6.40 \times 10^{-9}\ m^2}$$

The area of a circle is related to its diameter $\boldsymbol{D}$ by

$\boldsymbol{A} = \frac{\boldsymbol{\pi D^2}}{\mathbf{4}}$ Solving for the diameter $\boldsymbol{D}$, and substituting the value found for $\boldsymbol{A}$, gives

$$\boldsymbol{D} = 2(\frac{\boldsymbol{A}}{\boldsymbol{p}})^{\frac{1}{2}} = 2(\frac{\mathbf{6.40 \times 10^{-9}\ m^2}}{\mathbf{3.14}})^{\frac{1}{2}}$$

$$= \mathbf{9.0 \times 10^{-5}\ m}$$

Discussion

The diameter is just under a tenth of a millimeter. It is quoted to only two digits, because $\boldsymbol{\rho}$ is known to only two digits.

8. (5 points) Calculate the drift velocity of electrons in a 12-gauge copper wire (which has a diameter of 2.053 mm) carrying a 20.0-A current, given that there is one free electron per copper atom. (Household wiring often contains 12-gauge copper wire, and the maximum current allowed in such wire is usually 20 A.) The density of copper is $\mathbf{8.80 \times 10^3\ kg/m^3}$.

Solution:

First, calculate the density of free electrons in copper. There is one free electron per copper atom. Therefore, is the same as the number of copper atoms per $\mathbf{m^3}$. We can now find $\boldsymbol{n}$ as follows:

$$n = \frac{1\ e^-}{\text{atom}} \times \frac{6.02\times10^{23}\ \text{atoms}}{\text{mol}} \times \frac{1\ \text{mol}}{63.54\ \text{g}} \times \frac{1000\ \text{g}}{\text{kg}} \times \frac{8.80\times10^{3}\ \text{kg}}{1\ \text{m}^3}$$

$$= 8.342 \times 10^{28}\ e^-/\text{m}^3$$

The cross-sectional area of the wire is

$$A = \pi r^2$$

$$= \pi \left(\frac{2.053\times10^{-3}\ \text{m}}{2}\right)^2$$

$$= 3.310 \times 10^{-6}\ \text{m}^2$$

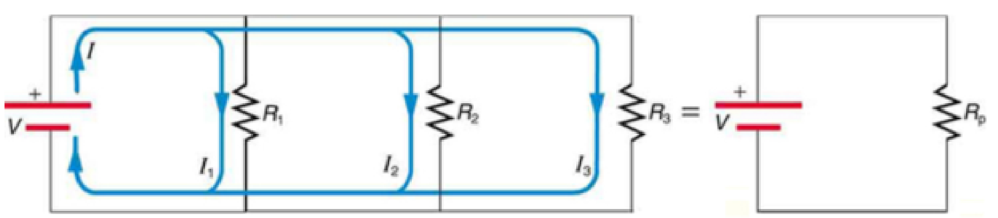
Rearranging $\boldsymbol{I = nqAv_d}$ to isolate drift velocity gives

$$v_d = \frac{I}{nqA} = \frac{20.0\ \text{A}}{(8.342\times10^{28}/\text{m}^3)(-1.60\times10^{-19}\ \text{C})(3.310\times10^{-6}\ \text{m}^2)} = -4.53 \times 10^{-4}\ \text{m/s}$$

Discussion

The minus sign indicates that the negative charges are moving in the direction opposite to conventional current. The small value for drift velocity (on the order of $\mathbf{10^{-4}\ m/s}$) confirms that the signal moves on the order of $\mathbf{10^{12}}$ times faster (about $\mathbf{10^{8}\ m/s}$) than the charges that carry it.

9. (5 points) Let the voltage output of the battery and resistances in the parallel connection in the figure below be: $\boldsymbol{V = 12.0\ \text{V}}$, $\boldsymbol{R_1 = 1.00\ \Omega}$, $\boldsymbol{R_2 = 6.00\ \Omega}$, and $\boldsymbol{R_3 = 13.0\ \Omega}$. (a) What is the total resistance? (b) Find the total current. (c) Calculate the currents in each resistor, and show these add to equal the total current output of the source. (d) Calculate the power dissipated by each resistor. (e) Find the power output of the source, and show that it equals the total power dissipated by the resistors.



Solution:

The total resistance for a parallel combination of resistors is found using the equation below. Entering known values gives

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{1.00\ \Omega} + \frac{1}{6.00\ \Omega} + \frac{1}{13.0\ \Omega}$. Thus,

$\frac{1}{R_p} = \frac{1.00}{\Omega} + \frac{0.1667}{\Omega} + \frac{0.07692}{\Omega} = \frac{1.2436}{\Omega}$ (Note that in these calculations, each intermediate answer is shown with an extra digit.)

We must invert this to find the total resistance $\boldsymbol{R_p}$. This yields

$\boldsymbol{R_p = \frac{1}{1.2436}\Omega = 0.8041\ \Omega}$. The total resistance with the correct number of significant digits is $\boldsymbol{R_p = 0.804\ \Omega}$

Discussion for (a)

$\boldsymbol{R_p}$ is, as predicted, less than the smallest individual resistance.

Strategy and Solution for (b)

The total current can be found from Ohm's law, substituting $\boldsymbol{R_p}$ for the total resistance. This gives

$\boldsymbol{I = \frac{V}{R_p} = \frac{12.0\ V}{0.8041\ \Omega} = 14.92\ A}$ Discussion for (b)

Current $\boldsymbol{I}$ for each device is much larger than for the same devices connected in series (see the previous example). A circuit with parallel connections has a smaller total resistance than the resistors connected in series.

Strategy and Solution for (c)

The individual currents are easily calculated from Ohm's law, since each resistor gets the full voltage. Thus,

$\boldsymbol{I_1 = \frac{V}{R_1} = \frac{12.0\ V}{1.00\ \Omega} = 12.0\ A}$. Similarly,

$\boldsymbol{I_2 = \frac{V}{R_2} = \frac{12.0\ V}{6.00\ \Omega} = 2.00\ A}$ and

$\boldsymbol{I_3 = \frac{V}{R_3} = \frac{12.0\ V}{13.0\ \Omega} = 0.92\ A}$.

Discussion for (c)
The total current is the sum of the individual currents:

$\boldsymbol{I_1 + I_2 + I_3 = 14.92\ A}$. This is consistent with conservation of charge.

Strategy and Solution for (d)

The power dissipated by each resistor can be found using any of the equations relating power to current, voltage, and resistance, since all three are known. Let us use $latex\boldsymbol{P = \frac{V^2}{R}}$, since each resistor gets full voltage. Thus,

$\boldsymbol{P_1 = \frac{V^2}{R^1} = \frac{(12.0\ V)^2}{1.00\ \Omega} = 144\ W}$. Similarly,

$\boldsymbol{P_2 = \frac{V^2}{R^2} = \frac{(12.0\ V)^2}{6.00\ \Omega} = 24.0\ W}$ and

$\boldsymbol{P_3 = \frac{V^2}{R^3} = \frac{(12.0\ V)^2}{13.0\ \Omega} = 11.1\ W}$.

Discussion for (d)

The power dissipated by each resistor is considerably higher in parallel than when connected in series to the same voltage source.

Strategy and Solution for (e)

The total power can also be calculated in several ways. Choosing $\boldsymbol{P = IV}$, and entering the total current, yields

$\boldsymbol{P = IV = (14.92\ \mathrm{A})(12.0\ \mathrm{V}) = 179\ \mathrm{W}}$. Discussion for (e)

Total power dissipated by the resistors is also 179 W:

$\boldsymbol{P_1 + P_2 + P_3 = 144\ \mathrm{W} + 24.0\ \mathrm{W} + 11.1\ \mathrm{W} = 179\ \mathrm{W}}$. This is consistent with the law of conservation of energy.

10. (5 points) For more questions regarding resistance, refer to the bonus questions' solutions posted.

11. (1 point) What is the SI unit of electrical conductivity?

Solution:

We know the SI unit of resistivity is Ωm, that makes the SI unit of conductivity $\frac{1}{\Omega m}$(since resistivity is the reciprocal of conductivity.)