St John Baptist De La Salle Catholic School, Addis Ababa

Grade 10 Physics Midterm Examination 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. (2 points) Which of the following is true about capacitance?
   A. The energy stored in a capacitor doubles when the capacitance is doubled.(**Correct Answer**)
   B. The energy stored in a capacitor decreases when a dielectric is present.
   C. The capacitance of two capacitors is greater when they are connected in series.
   D. The permissivity of free space is greater than the permissivity of dry wood.
2. (2 points) Consider an RC Circuit, how do we expect it to behave?(More than one answer could be true)
   A. When it charges, it takes **RC** amount of time to get to 37 percent of intended voltage.
   B. When it charges, it takes **RC** amount of time to get to 63 percent of intended voltage.(**Correct Answer**)
   C. When it discharges, it takes **RC** amount of time to get to 37 percent of its initial voltage.(**Correct Answer**)
   D. When it discharges, it takes **RC** amount of time to get to 63 percent of its initial voltage.

3. (2 points) What charge is stored in a parallel plate capacitor of area $1.00m^2$ and separation 1.00mm if a voltage of $3.00x10^3V$ is applied to it?($\varepsilon_0 = 8.85X10^{-12}$)
   A. 8.85nF
   B. 26.6 μC(**Correct Answer**)
   C. 266μC
   D. 8.85μC

4. (2 points) What is the electron density of a conductor in e/m^3 if the current flowing through it is 4A, the drift velocity is 10^{-5}m/s, and the cross-sectional area of the conductor is 300 cm^2
   A. $9.20X10^{25}$
   B. $7.3X10^{-22}$
   C. $8.33X10^{25}$(**Correct Answer**)
   D. None of the above

5. (2 points) Which of the following is true about resistance?
   A. The resistance of an object decreases when the length of the object is increased.
   B. The resistance of an object decreases by a factor of four if the cross-sectional radius is doubled.(**Correct Answer**)
   C. The resistance of an object does not depend on temperature.
   D. The resistance of an object is not affected by the material from which it is made.
   E. The resistance of an object decreases by a factor of two if the cross-sectional diameter is doubled.

6. (2 points) How long does it take electrons to get from a car battery to the starting motor? Assume the current is 300 A and the electrons travel through a copper wire having a radius of 0.5mm and length 0.85 m. The number of charge carriers per unit volume is 8.49 X 10^{28}e/m^3.
   Solution: First, we find the total charges in the given conductor.

$$Q = nVe, \text{where n is the electron density, V is the volume and e is the electron charge} \tag{1}$$

We then find the volume using the following formula

$$V = \text{Area * length} \tag{2}$$

$$Area = \pi r^2 = \pi(5.0 \text{ X } 10^{-4}\text{m})^2 \tag{3}$$

We then get the area to be 2.5 X $10^{-7}m^2$, then multiplying the area that we found by the volume, we get V = 2.125 X $10^{-7}m^3$.
After this, we use equation one to find the number of charges.

$$Q = (8.49X10^{28}\text{e}/m^3) * 2.125X10^{-7}m^3 * 1.6 \text{ X } 10^{-19}C \tag{4}$$

We then find the charge to be,

$$Q = 2.89 \text{ X } 10^3 C \tag{5}$$

After we find the charge, it is quite easy to find the current.

$$t = \frac{Q}{I} = \frac{2.89 \times 10^3 C}{300 A} \tag{6}$$

We find the time to be 9.62 seconds.

7. (2 points) There are 4 capacitors in a circuit which all have the same capacitance of 3μF. If the two of the capacitors are connected in series to the battery while the other two are parallel, construct the circuit and find the effective capacitance of the circuit. Find the charge through each capacitor.

Solution:
We first need to find the effective capacitance of the whole circuit. Since all of the same capacitance we can find an expression for the effective capacitance of the circuit as a whole.

The two capacitors connected in series have an effective capacitance of $\frac{C}{2}$, while those connected in parallel have a capacitance of 2C. Then to find the effective capacitance of the circuit as a whole, we add the capacitances in series as we normally would and we get the capacitance to be $\frac{2C}{5}$, where C is the capacitance of each resistor(since they all have the same resistance.)
Therefore:

$$C_T = \frac{2 * 3\mu F}{5} = \frac{6}{5}\mu F$$

Let the potential difference provided by the battery be V. That means the charge in the circuit is

$$Q = CV = (\frac{6}{5}\mu F)(V)$$

Therefore, the charge through the capacitors in series is the same as this charge. That means the voltage through both of them is

$$V_{12} = \frac{Q}{3\mu F}$$

That means, the voltage in the capacitors in parallel is the total voltage minus V_{12}, which is

$$V_{34} = V - \frac{2Q}{3\mu F} = \frac{Q}{\frac{6}{5\mu F}} - \frac{2Q}{3\mu F} = \frac{5Q}{6\mu F} - \frac{2Q}{3\mu F}$$

$$V_{34} = \frac{Q}{6\mu F}$$

That means the charge stored in each charged in each of these capacitors that is connected in parallel is

$$Q_{34} = (3\mu F)(\frac{Q}{6\mu F}) = \frac{Q}{2}$$

8. (5 points) In open heart surgery, a much smaller amount of energy will defibrillate the heart. (a) What voltage is applied to the 8.00 μF capacitor of a heart defibrillator that stores 40.0 J of energy? (b) Find the amount of stored charge. **Solution:**
(a)

$$E = \frac{1}{2}CV^2$$

$$40.0J = \frac{1}{2}(8.00\mu F)V^2$$

$$10 \times 10^6 V^2 = V^2$$

$$V = 3.16 \times 10^3 V$$

(b)

$$Q = CV$$

$$Q = (8.00\mu F)(3.16 \times 10^3 V)$$

$$Q = 2.53 \times 10^{-2} C$$

9. (5 points) Derive an expression for the effective resistance of three resistors connected in parallel. If the resistors each have a resistance of 2 Ohm, 4 Ohm, and 8 Ohm respectively, find the total resistance of the resistors using the expression you found. If the potential difference provided by the battery is 8V, find the current through each resistor. **Solution:**

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{R_2R_3 + R_1R_3 + R_1R_2}{R_1R_2R_3}$$

$$R_T = \frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2}$$

Thus, using our equation here, we can find the effective resistance:

$$R_T = \frac{2\Omega * 4\Omega * 8\Omega}{4\Omega * 8\Omega + 2\Omega * 8\Omega + 2\Omega * 4\Omega} = \frac{64}{56}\Omega$$

$$R_T = 0.875\Omega$$

Since the voltage is the same through each resistor(since they are connected in parallel), we find the current through each resistor is:
The current through the 2Ω resistor is:

$$I_2 = \frac{8V}{2\Omega} = 4A$$

The current through the 4Ω resistor is:

$$I_2 = \frac{8V}{4\Omega} = 2A$$

The current through the 8Ω resistor is:

$$I_2 = \frac{8V}{8\Omega} = 1A$$

10. (5 points) In a specific thermocouple thermometer, a current of 7mA flows when the temperature difference between the two ends is 70K. If one of the solutions on one end is boiling water, and the reading on our ammeter is 28mA, find the temperature of the other solution.(Hint: The change in temperature in K is the same as the change in temperature in Celsius)
Solution:
It is known that the change in temperature in K is the same as the change in ^0C, there for $\Delta T = 70K = 70^0C$ This means for the current to be 28mA, there should be a 280^0C temperature difference between the two ends. If one end is boiling water, then the Temperature of the other end is 380^0C or -180 ^0C.

11. (1 point) What is the SI unit of resistivity? Derive an expression for resistivity in terms of length, area and resistance.
Solution: Let us first find the expression of resistivity.
We know that

$$R = \frac{\rho l}{A},$$

rearranging the expression, we get

$$\rho = \frac{RA}{l}$$

To determine the SI unit, we replace all the other quantities with their SI units and end up with the SI unit of resistivity which is Ωm.