Homework No. 05 (Fall 2023)

PHYS 205B: UNIVERSITY PHYSICS

School of Physics and Applied Physics, Southern Illinois University–Carbondale
Due date: Thursday, 2023 Oct 5, 9:30 AM, on D2L

Instructions

- You are encouraged to use any of the resources to complete this homework. However, the extent to which you depend on resources while doing homework is usually a measure of how much extra work you need to put in to master the associated concepts. Solutions should be the last resource.

- Describe your thought process in detail and organize it clearly. Make sure your answer has units and the right number of significant digits.

- After completion, scan the pages as a single PDF file, and submit the file on D2L (under Assessments → Assignments).

Problems

1. (**10 points.**) Estimate the drift velocity of conduction electrons in a copper wire of radius 1.0 mm using

$$I = neAv_d. \tag{1}$$

   Copper has one free electron per atom available for conduction. For reference copper wire has 9×10^{28} atoms/m^3. Use $I = 1.0$ A. How much time (in hours) does it take for an individual electron to begin from the light switch and reach the bulb that is connected by a 2.0 m long copper wire?

   Solution

2. (**10 points.**) Watt is the unit of power. Watt-hour is a unit of energy. How much is kWh (kilo Watt-hour) in Joules? The average cost of electricity in the United States, for residential users, is about 0.15 USD/kWh (15 cents per kiloWatt-hour). At this rate your electricity bill for a month came out to be 50.00 USD. How much electric energy (in Joules) did you use in the month?

   Solution

3. (**10 points.**) Resistance is inversely proportional to the area of crosssection A and proportional to the length l, such that

$$R = \frac{\rho l}{A}, \tag{2}$$

where ρ is the resistivity of the material. A cylindrical copper rod has resistance R. It is reformed to thrice its original length with no change of volume. What is its new resistance in terms of the original resistance R?

Solution

4. (**10 points.**) Figure 1 shows three resistors connected in parallel to a battery. The battery has a voltage of $V = 10.0\,\mathrm{V}$, and the resistors have equal resistances of $R = 300.0\,\Omega$.

   (a) Determine the equivalent resistance across the battery.

   (b) Determine the voltage across each of the resistor.

   (c) Determine the current passing through each resistor.
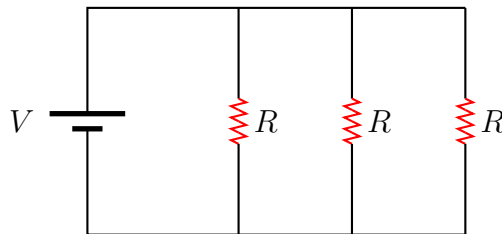
   (d) Determine the power consumed by each resistor.

Figure 1: Problem 4

Solution

5. (**10 points.**) Consider the circuit in Figure 2 with $V_1 = 10\,\mathrm{V}$, $V_2 = 20\,\mathrm{V}$, $R_1 = 10\,\Omega$, $R_2 = 20\,\Omega$. For what resistance R_3 is the current in R_1 zero?
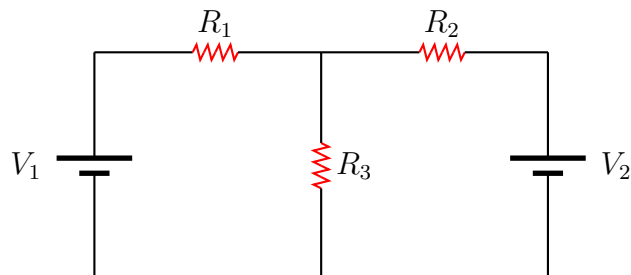

Figure 2: Problem 5

Solution

6. (**10 points.**) Consider the circuit in Figure 3 with $V_1 = 10.0\,\text{V}$, $V_2 = 20.0\,\text{V}$, –More– (64Unsupported return type 65 QPixmap in method "grab" Unsupported return type 1087 QAction* in method "addAction" Skipped method "setDefaultShortcuts" : Pointers are not supported: QAction* $R_1 = 10.0\,\Omega$, $R_2 = 20.0\,\Omega$, $R_3 = 30.0\,\Omega$.

   (a) Find the currents i_1, i_2, and i_3 (with directions) through each of the resistors.

   (b) Find the potential differences V_{R1}, V_{R2}, and V_{R3} across each of the resistors.

   (c) Find the power P_1, P_2, and P_3 lost in each of the resistors.
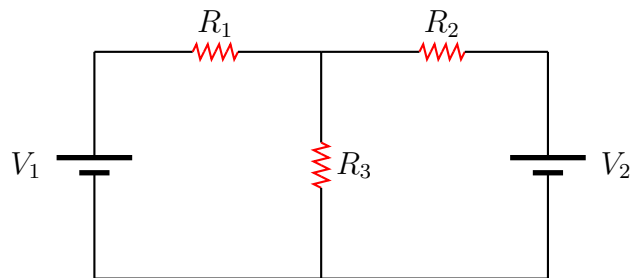

Figure 3: Problem 6

Solution

7. (**10 points.**) Consider the process of charging the capacitor C in Figure 7.
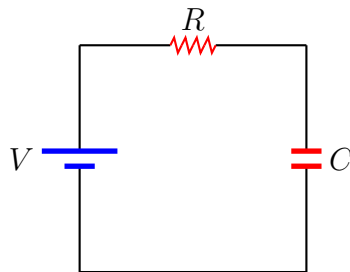

Figure 4: Problem 7

   (a) Using Kirchoff's law, write down the (differential) equation relating the current I in the circuit and the charge Q on the capacitor.

   (b) The solution to the equation, in Question (7a), for the initial condition $Q(0) = 0$ is given by
   $$Q(t) = CV \left[1 - e^{-\frac{t}{RC}} \right]. \tag{3}$$

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What is the maximum charge the capacitor attains? How much time does it take to charge the capacitor to this maximum value? How much time does it take to charge the capacitor to half of the maximum value? Given $C = 10.0\,\mu\text{F}$, $R = 30.0\,\text{k}\Omega$, and $V = 10.0\,\text{V}$.

Solution