A Level Physics

ELECTRICAL CIRCUITS:
Complete Circuits 1 (Answers)

Name:

Total Marks: /30
1. Define electrical work, \( W \), in terms of potential difference, \( V \), and charge, \( Q \). Using this relationship, show that \( P = I^2R \)

**Solution:** \( W = VQ \)
But, \( Q = It \) and \( P = W/t \rightarrow P = VIt/t = VI \)
From Ohm’s law, \( V = IR \rightarrow P = I^2R \)

(b) The P.D. across a 5.0 \( \Omega \) resistor is measured as 6.0 V. What power is it dissipating?

**Solution:** 7.2 W

(c) An LED is connected in series with an ammeter and a power supply. A voltmeter is connected across the LED. They read 2.2 A and 4.6 V. If it is left on for 1 hour and 15 minutes, how much work is done by the LED?

**Solution:** 45 kj
(d) Sketch how the electrical work done by the resistor at a given point in time would vary with the resistance of the resistor. Assume the P.D. across the resistor is constant.

**Solution:** $y \propto 1/x$ graph i.e. nonlinear decrease
2. This question exploits Kirchoff’s laws to determine the resistances of several components in Figure 1.

Figure 1: A circuit containing two resistors, a voltmeter, an ammeter, a cell and a bulb.

Tom notes that the bulb has an effective resistance of 5.0 Ω, that the voltmeter reads 2.0 V and that the ammeter reads 3.5 A.

(a) State Kirchoff’s First Circuit Law. What implications does it have for the charge entering and leaving a circuit junction?

**Solution:** Sum of currents entering a junction equals the sum of currents leaving a junction

\[ \sum I_{\text{into junction}} = \sum I_{\text{out of junction}} \]

Since \( Q = It \), the same conservation applies at a junction for charge.

(b) State Kirchoff’s Second Circuit Law.

**Solution:** In a given closed loop, the sum of the potential differences is equal to the sum of the EMFs: \( \sum PD_i = \sum EMF_i \)

(c) Calculate \( R_1 \).

**Solution:** 0.57 Ω
(d) Calculate \( R_2 \).

\[
\text{Solution: } 6.7 \, \Omega
\]

(e) Calculate the power dissipated by the bulb.

\[
\text{Solution: } 20 \, W
\]

(f) The bulb dissipates 75\% of its power as heat and converts the rest to light. What is the efficiency of this circuit as a means of lighting?

\[
\text{Solution: } 12\%
\]
3. Based on the conservation of charge and of energy, it is possible to derive several laws that dictate how the total effective resistance in a circuit varies when a combination of resistors are used in series and/or parallel.

Total for Question 3: 8

(a) Use Kirchoff’s and Ohm’s laws to derive an expression for the total effective resistance of two resistors, $R_{1−2}$, in series.

Solution: From KSL and Ohm’s: $IR = I_1R_1 + I_2R_2$
From KFL $I$ is the same for all $→ R = R_1 + R_2$

(b) Using a similar technique, show that for two resistors in parallel, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$.

Solution: KFL: $I = I_1 + I_2$
Incorporating Ohms: $\frac{V}{R} = \frac{V_1}{R_1} + \ldots$
KSL: $V$ of each loop is the same $→ V = V_1 = V_2 → \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

(c) Two resistors ($1.0 \, \Omega$ and $2.0 \, \Omega$) connected in parallel are linked in series to a $3.0 \, \Omega$ resistor. All of this is in parallel with a fourth resistor. If the total effective resistance is $1.0 \, \Omega$, what is the resistance of the fourth resistor?

Solution: $1.4 \, \Omega$
4. Draw the symbols for the following circuit components:

(a) An LED.

Solution:

(b) A variable resistor.

Solution:

(c) A thermistor.

Solution:

(d) An LDR.

Solution: