Problem 12.1 A battery has an emf of 12.8 V and supplies current of 3.2 A. What is resistance of circuit? How many coulombs leave battery in 5 minute?

\[ V = 12.8 \text{ V} \quad i = 3.2 \text{ A} \quad R = ? \quad Q = ? \quad \text{if } t = 5 \text{ min} = 300 \text{ sec} \]

**Solution**

From Ohm's law we can write \[ R = \frac{V}{i} = \frac{12.8}{3.2} = 4 \text{ } \Omega \]

Now charge \[ Q = i \times t = 3.2 \times 300 = 960 \text{ C} \]

Problem 12.2 A carbon electrode has a resistance of 0.125 Ω at 20 °C. The temperature co-efficient of carbon is -0.0005 at 20 °C. What will be the resistance of the electrode at 85 °C.

\[ R_{20} = 0.125 \text{ } \Omega \quad T_1 = 20 \text{ °C} \quad \alpha = -0.0005 \quad R_t = ? \quad \text{when } T_2 = 85 \text{ °C} \]

**Solution**

Resistance at any temperature \( T \) is given by

\[ R_t = R_{o} (1 + \alpha T) \]

where \[ T = T_2 - T_1 = 85 - 20 = 65 \text{ °C} \]

\[ R_t = 0.125 (1 - 0.0005 \times 65) = 0.12 \text{ } \Omega \]

Problem 12.3 Calculate the resistance of wire 10 m long that has a diameter of 2 mm and resistivity of 2.63 x 10^-2 Ω m.

\[ R = ? \quad L = 10 \text{ m} \quad d = 2 \text{ mm} = 2 \times 10^{-3} \text{ m} \quad \rho = 2.63 \times 10^{-2} \text{ Ω m} \]

**Solution**

we know that \[ R = \frac{\rho L}{A} \]

where \( A = \pi r^2 = \pi d^2 / 4 = 3.14 \times 10^{-6} \text{ m}^2 \)

\[ R = \frac{(2.63 \times 10^{-2})(10)}{3.14 \times 10^{-6}} = 83758 \text{ Ω} \]

(Text book needs correction)

Problem 12.4 A typical 12 V automobile battery has a resistance of 0.012 Ω. What is terminal voltage of this battery when starter draws a current of 100 A? Calculate \( P_e, P_R \) and \( P_t \).

\( \varepsilon = 12 \text{ V} \quad r = 0.012 \text{ Ω} \)

(a) \( V_t = ? \) when \( i = 100 \text{ A} \)

(b) Load \( R = ? \)

(c) Power of source \( P_e = ? \)

(d) Power \( P_R = ? \)

(e) Power \( P_t = ? \)

**Solution**

(a) We know that emf \( \varepsilon = V_t + ir \)

\[ V_t = \varepsilon - ir = 12 - (100)(0.012) = 10.8 \text{ V} \]

(b) Load resistor

\[ R = \frac{V_t}{i} = \frac{10.8}{100} = 0.108 \text{ Ω} \]
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(c) \[ P_e = i^2 (R + r) = (100)^2 \times (0.108 + 0.012) = 1200 \text{ W} \]

(d) \[ P_R = i^2 R = (100)^2 \times 0.108 = 1080 \text{ W} \]

(e) \[ P_f = i^2 r = (100)^2 \times 0.012 = 120 \text{ W} \]

Problem 12.5. A 10 W resistor has a value of 120 Ω. What is the rated current through the resistor?

\[ P = 10 \text{ W} \quad R = 120 \Omega \quad i = ? \]

**Solution**

From definition of power \( P = i^2 R \)

\[ i = \sqrt{\frac{P}{R}} = \sqrt{\frac{10}{120}} = 0.2886 \text{ A} \]

**The maximum current that a device can draw without being over-heated is called rated current.**

Problem 12.6 Resistor of 50 Ω has a P. D of 100 V D.C. across 1 hr. Calculate (a) Power and (b) Energy.

\[ R = 50 \Omega \quad V = 100 \text{ V} \quad t = 1 \text{ hr} = 3600 \text{ sec} \quad (a) \ P = ? \quad (b) \ E = ? \]

**Solution**

(a) Power

\[ P = \frac{V^2}{R} = \frac{(100)^2}{50} = 200 \text{ w} \]

(b) Energy

\[ E = P \times t = 200 \times 3600 = 0.72 \times 10^6 \text{ J} = 0.72 \text{ MJ} \]

Problem 12.7 Calculate the current through a single loop circuit if \( \varepsilon = 120 \text{ V}, R = 1000 \Omega \) and internal resistance \( r = 0.01 \Omega \).

\[ \varepsilon = 120 \text{ V} \quad R = 1000 \Omega \quad r = 0.01 \Omega \]

**Solution**

Using the relation \( \varepsilon = i (R + r) \)

or \( i = \frac{\varepsilon}{R + r} = \frac{120}{1000 + 0.01} = 0.1199 \text{ A} \) or 120 mA

Problem 12.9 Find current flowing through the resistors of the figure given.

Current \( i = ? \) in the given circuit

Let \( \varepsilon_1 = 10 \text{ V} \quad \varepsilon_2 = 6 \text{ V} \quad R_1 = 2 \Omega \quad R_2 = 1 \Omega \quad i = ? \]

**Solution**

Applying KVL along closed loop abcda (counter clockwise)

\[ -\varepsilon_1 - (i_1 - i_2) R_1 = 0 \]

\[ -10 - (i_1 - i_2) R_1 = 0 \] (1)

Similarly applying KVL along the closed loop befcb (counter clockwise)

\[ -i_2 R_2 + \varepsilon_2 - (i_1 - i_2) R_1 = 0 \]

\[ -i_2 R_2 + 6 - (i_1 - i_2) R_1 = 0 \]
Adding eq (1) and (2) we get
\[ +6 - i_2 R_2 - (i_1 - i_2) R_1 = 0 \]  
\[ \text{eq (2)} \]
putting this value in eq (1) we get
\[ - i_2 R_2 - 4 = 0 \]
\[ i_2 = -4 \text{ A} \]
solving for \( i_1 \) we get
\[ -2 i_1 + 2 (-4) - 10 = 0 \]
\[ i_1 = -9 \text{ A} \]

Current flowing through \( R_2 \) is \( i_2 = -4 \text{ A} \) and current flowing through \( R_1 \) is \( (i_1 - i_2) = -5 \text{ A} \)

**Problem 12.10** Find terminal P.D of each cell in the circuit of figure given.

\( r_1 = 0.1 \text{ } \Omega \) \quad \( r_2 = 0.9 \text{ } \Omega \) \quad \( R = 8 \text{ } \Omega \) \quad \( \varepsilon_1 = 24 \text{ V} \)

\( \varepsilon_2 = 6 \text{ V} \) \quad \( V_{t_1} = ? \) \quad \( V_{t_2} = ? \)

**Solution**

Since \( \varepsilon_1 \) and \( \varepsilon_2 \) oppose each other so net emf is equal to their difference. Resistors are all in series, so net resistance is equal to the sum of individual resistance.

\[ i = \frac{\varepsilon}{R_{\text{net}}} = \frac{\varepsilon_1 - \varepsilon_2}{r_1 + r + r_2} \]

\[ i = \frac{24 - 6}{0.1 + 8 + 0.9} = 2 \text{ A} \]

Now terminal P.D of both cells can be calculated as follow;

For 1\(^{st} \) cell: eq(1)\( \Rightarrow \)
\[ V_{t_1} = \varepsilon_1 - i r_1 = 24 - (2 \times 0.1) = 23.8 \text{ V} \]

For 2\(^{nd} \) cell: eq(1)\( \Rightarrow \)
\[ V_{t_2} = \varepsilon_2 + i r_2 = 6 + (2 \times 0.9) = 7.8 \text{ V} \]

**Problem 12.11** Voltmeter in circuit may be considered to be ideal. Values are \( \varepsilon = 15 \text{ V} \), internal resistance \( r = 5 \text{ \Omega} \), \( R_1 = 100 \text{ \Omega} \), \( R_2 = 300 \text{ \Omega} \). Calculate current in \( R_1 \).

**Solution**

\( \varepsilon = 15 \text{ V} \) \quad \( r = 5 \text{ \Omega} \) \quad \( R_1 = 100 \text{ \Omega} \) \quad \( R_2 = 300 \text{ \Omega} \)

Current \( i = ? \) through \( R_1 \)

First we need to calculate equivalent resistance \( R_{\text{eq}} \) as the given circuit contains more than one resistors. Ideal voltmeter has infinite resistance, so there will be no current through it.

\( R_1 \) and \( R_2 \) are in parallel so their net resistance will be
\[ R' = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{100 \times 300}{100 + 300} = 75 \, \Omega \]

Now this \( R' \) is in series with \( r \) in the circuit. So we further simplify the circuit to find total resistance. So
\[ R_{eq} = R' + r = 75 + 5 = 80 \, \Omega \]

Now from Ohm’s law
\[ i = \frac{\varepsilon}{R_{eq}} = \frac{15}{80} \]
\[ i = 0.1875 \, \text{A} \]

Now this current “\( i \)” will pass through both \( r \) and \( R' \). Potential drop across \( R' \) is the terminal potential difference \( V_t \) and is given by
\[ V_t = i \times R' = 0.1875 \times 75 \]
\[ V_t = 14.06 \, \text{V} \]

Now current through \( R_1 \) will be
\[ i_1 = \frac{V_t}{R_1} = \frac{14.0625}{100} \]
\[ i_1 = 0.1406 \, \text{A} \] (textbook needs correction)