Ohm’s Law Example Solutions

Physics, 7th Edition, Cutnell & Johnson
Chapter 20.2
Pages 605-607

Important Formulae

\[ V_{AB} = IR \]
\[ I = \frac{V_{AB}}{R} \]
\[ R = \frac{V_{AB}}{I} \]

\[ P = \frac{W}{\Delta t} = V_{AB} I \]
\[ P = IRI = I^2 R \]
\[ P = V_{AB} \frac{V_{AB}}{R} = \frac{V_{AB}^2}{R} \]
Example 1
Phototube Circuit

Solution:

- What can we say about this circuit??
  - I is clockwise
  - $V_{AG} = 10V$
  - $V_{R1} = 6V$
  - $V_{R2} = 4V$
  - $R1 = (3/2)R2$
Example 2
A Simple (but important) Circuit

- Consider the following circuit.

- What is the voltage across the resistor ($V_{AB}$)?
- What current through the resistor?
- What is $V_A$? $V_B$?

Example 2
Solution: (12V,1.2A,???)

a) Wires are equipotential contours (i.e., energy level contours). Therefore, starting at point B going clockwise to A shows $V_{AB} = 12\, V$.

b) Use Ohm's law to find the current through the resistor:

\[ I = \frac{V_{AB}}{R} = \frac{12\, V}{10\, \Omega} = 1.2\, A \]

(c) ???
Example 3
Ammeter Circuit

Consider the following circuit containing an ammeter (used to measure current)

What is E??
What is the resistance of the ammeter??

Solution: (12V)

\[ V_{ab} = E \]
From Ohm's law:
\[ V_{ab} = IR = (1.5\text{A})(8\Omega) = (1.5\text{A})\left(8 \frac{V}{A}\right) = 12\text{V} \]
\[ \therefore E = V_{ab} = 12\text{V} \]

The resistance of the ammeter is assumed to be 0Ω. But is it really??
Example 4
Ammeter and Voltmeter Circuit

- Consider the following circuit containing a voltmeter (used to measure voltage):

- The voltmeter reads 9.00 volts and the ammeter reads 300 mA.
  - What is the resistance of the resistor R??
  - What is the resistance of the voltmeter??

Example 4
Solution: (30Ω)

\[ I = 300\text{mA} = 0.300\text{A} \]
\[ V_{AB} = E = 9.00\text{V} \]

Using Ohm's law:
\[ V_{AB} = IR \]
\[ R = \frac{V_{AB}}{I} = \frac{9.00\text{V}}{0.300\text{A}} = 30.0\Omega \]

- The resistance of the voltmeter is assumed to be \( \infty \Omega \). But is it really??
Example 5
Electrical Energy Conversion

Consider the following circuit

\[ E = 1.5V \]
\[ R = 1\, \Omega \]

At what rate is electrical energy converted to heat by the resistor in the circuit?

Example 5
Solution:

(2.25W)

Use Ohm's Law to find the current:

\[ V_{ab} = 1.5\, V \]
\[ V_{ab} = IR \]

\[ I = \frac{V_{ab}}{R} = \frac{1.5\, V}{1\, \Omega} = 1.5\, A \]

\[ P = V_{ab}I = (1.5\, V)(1.5\, A) = 2.25\, W \]

Note: This is a lot of power for a resistor.
Example 6

Chemical Energy

- Consider the following circuit with \( E = 120 \, \text{V} \) and \( R = 144 \, \Omega \).

- At what rate does the resistor convert electrical energy to heat?
- At what rate does the battery convert chemical energy to electrical energy?

Solution:

\[
P = \frac{V^2}{R} = \frac{120^2}{144} = 100 \, \frac{V^2}{\Omega} = 100 \, \frac{V^2}{A} = \text{100 VA}
\]

\[
P = 100 \, \text{VA} = 100 \left( \frac{1}{\text{s}} \right) \left( \frac{\text{C}}{\text{s}} \right) = 100 \, \text{W}
\]

The resistor converts electrical energy to heat at the rate of 100 W. The battery converts chemical energy to electrical energy at the same rate: 100 W.