Lesson 1

OHM'S Law

ACMA Syllabus February 2024 Chapters 1.1 and 1.2

Contents

Electricity.

The phenomenon of the electric charge was discovered many years ago. Initially this was in the form of static electricity generated by lightning or from the friction of two materials. Today, electricity is better understood and an essential commodity.

Electricity can be described as the flow of electrons. Materials that resist the flow of electrons are called ***insulators*** and the materials that allow the flow of electrons are called ***conductors***. A semiconductor has conductivity between an insulator and a conductor. This is made possible by the addition of an impurity or because of temperature effects. Semiconductors are essential components of most electronic circuits.

Firstly, we need a source of electrons. A ***Cell*** is a device in which a chemical reaction between materials can produce electrons. The voltage of a cell is approximately 1.5V. See the symbol for a cell in Figure 1.

Many cells connected are called a ***battery***. See the symbol for a battery in Figure 1.

A battery is rated in ampere-hours.

Example: A battery rated at 10 amp-hours could supply 10 amps for 1 hour, 1 amp for 10 hours or 5 amps for 2 hours.

Sources

A disposable battery is termed a *primary battery* and one that can be charged is termed a *secondary battery*.

Internal resistance is the resistance within a battery, or other voltage sources, that causes a drop in the source voltage when there is a current. A cell can be thought of as a source of EMF with a resistor connected in series. When current flows through the cell a voltage develops across the internal resistance

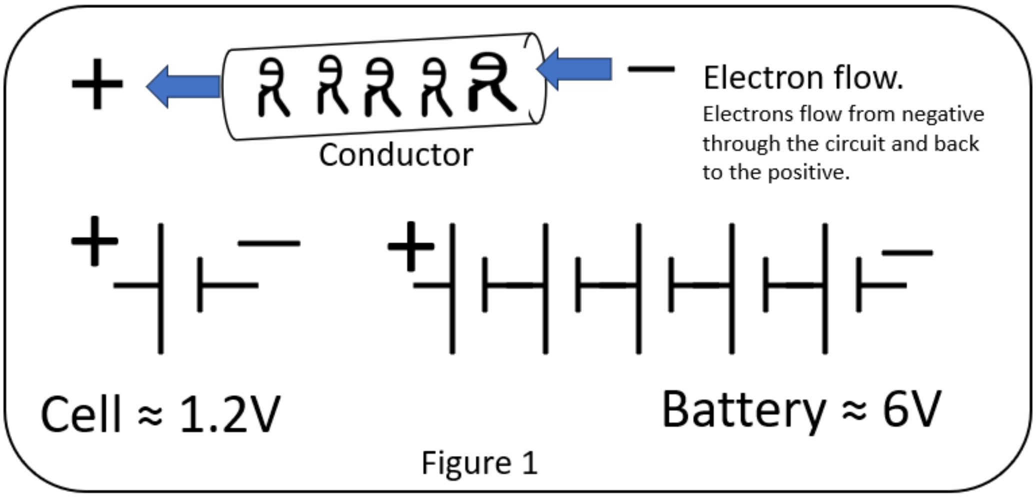
Terminal voltage: When current is drawn from a cell, the potential difference between the electrodes of the cell is called its terminal voltage.

Current Flow

The constant flow of electrons from a battery or cell is termed “Direct Current” (DC). Current flow that changes direction on a regular basis is termed “Alternating current” (AC). This lesson is based on DC and AC will be addressed later.

Electron Flow

When electricity was first discovered, the belief was that the energy flowed from positive (+) to negative (-). This was termed conventional current flow. When electricity was better understood, scientists realized that the flow of electrons was electricity, and the electrons flowed from negative (-) to positive (+). This is termed electron flow.

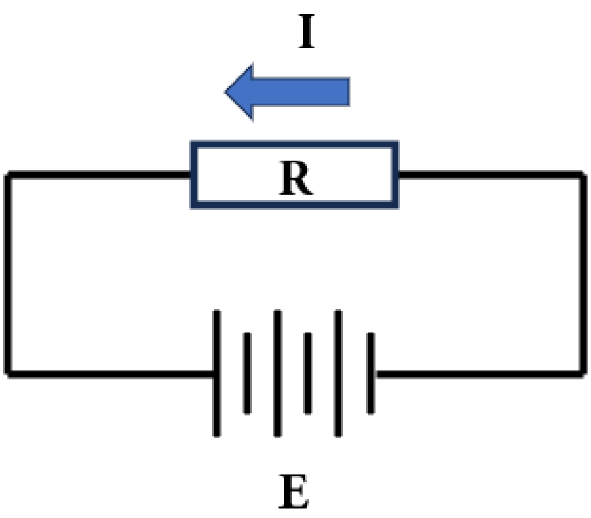


Introducing Ernie, the electron.

The force, or potential, to push the electrons through the conductor is called the Electromotive Force (EMF) and is measured in volts (V or E).

The intensity of the current or quantity of electrons flowing through the conductor is measured in amperes or amps (I).

Any resistance to the flow of electrons is measured in Ohms represented by the Greek letter Omega (Ω).



Ohm's Law

In 1781 Georg Ohm documented the relationship between voltage, current and resistance. His findings were not published till 1879, and these are now known as Ohm's Law. The best way to use this law is through the Ohm's triangle shown in Figure 2.

To use the triangle, cover the unit you wish to calculate and the positions of the remaining two units dictate the formulae.

- To calculate the resistance R, cover the R and the other two units show E divided by I.
- To calculate the current I, cover the I and the other two units show as E divided by R.
- To calculate the voltage E, cover the E and the other two units show as I multiplied by R.

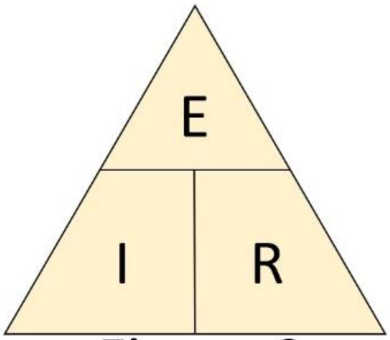


Figure 2

$$R = E \div I \qquad I = E \div R \qquad E = I \times R$$

Examples:

- What is E if R = 100 Ω and I = 0.2 A ?

  E= I x R = 100 x 0.2 = 20 V

- What is I if R = 100 Ω and E = 10 V?

  I = E/R = 10 / 100 = 0.1 A

- What is R if E = 12 V and I = 0.2 A

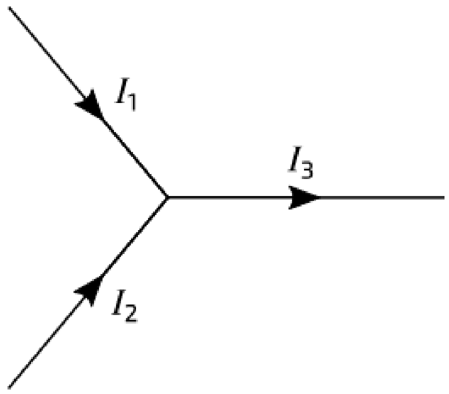
  R = E / I = 12 / 0.2 = 60 Ω

A **short circuit** is when an electrical current flows down an unintended path with very low impedance. This results in an extremely high current flowing through the circuit. This can happen if the battery terminals are shorted.

$$I = 12 / 0 = \infty$$ or infinity

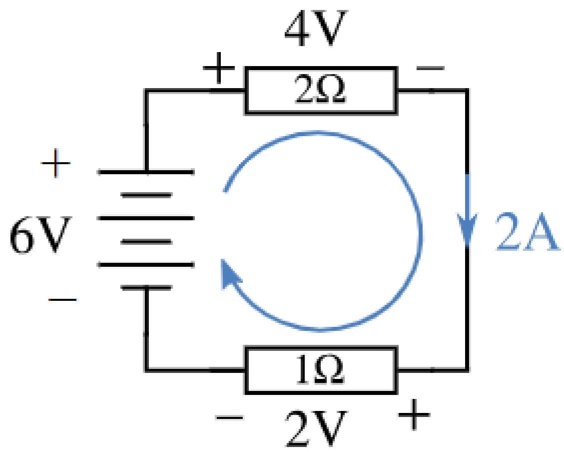
Kirchhoff's Laws (More in Lesson 4)

Kirchhoff's current law (1st Law) states that the current flowing into a node (or a junction) must be equal to the current flowing out of it.



$I_1 + I_2 = I_3$

Kirchhoff's voltage law (2nd Law) states that in any complete loop within a circuit, the sum of all voltages across components which supply electrical energy (such as cells or generators) must equal the sum of all voltages across the other components in the same loop.



Prefixes

In describing large or small values, a prefix, also called the "SI prefix", is used. The SI unit system changes every three digits. Commonly used prefixes are kilo (k), which means 1000 times, and mega (M), which means 1 million times. Smaller common prefixes are milli (m), which means 1/1000 and micro (μ) means 1/1000000.

Symbol	Word	Multiplier	Magnification
T	tera	10^{12}	1 million billion
G	giga	10^{9}	1 billion
M	mega	10^{6}	1 million
k	kilo	10^{3}	1 thousand
m	milli	10^{-3}	1 / 1 thousand
μ	micro	10^{-6}	1 / 1 million
n	nano	10^{-9}	1 / 1 billion
p	pico	10^{-12}	1 / 1 trillion

Using the prefixes, some common combinations you will encounter are as follows.

2 MΩ = 2 mega Ohms = 2 million Ohms

6 kV = 6 kilo volts = 6 thousand volts

5 mV = 5 milli volts = 0.005 V

7 μA = 7 micro amps = 0.000007 amps

Using the prefixes is far simpler than writing all the zeros.

The International System of Units

How do we know that a measurement we make here in Australia is going to be the same anywhere else in the world?

The International System of Units (SI) defines the measurement standards worldwide.

There are seven (7) base units from which any other measurements can be derived. The base units are shown below.

Unit	Symbol	Quantity
Second	s	Unit of time
Metre	m	Length
Kilogram	kg	Mass
Ampere	A	Electric current
Kelvin	K	Temperature
Mole	mol	Amount of substance
Candella	cd	Luminous intensity

There are twenty-two (22) coherent derived units with special names and symbols expressed as a product (or ratio) of one or more of the base units. Of the coherent derived units, there are twelve (12) which relate to these studies.

The names of SI coherent derived units are always in lowercase. However, the symbols for units named after persons are written with an uppercase initial letter. For example, the symbol for hertz is "Hz", while the symbol for metre is "m".

Name	Symbol	Quantity	Derivation
hertz	Hz	Frequency	Cycles per second
joule	J	Energy, Work, Heat	Coulomb volt
watt	W	Power	Joules per second
coulomb	C	Electric charge	Ampere second
volt	V	Electric potential	Joule per coulomb
farad	F	Capacitance	Coulomb volt
ohm	Ω	Resistance	Volt per ampere
henry	H	Inductance	Ohm second
siemens	S	Electrical conductance	Reciprocal of I Ohm
weber	Wb	Magnetic flux	Volt second
tesla	T	Magnetic flux density	Weber per square metre.
degrees Celsius	°C	Temperature	273.15 degrees Kelvin

Go to the Lesson 1 Questions.