Introduction to Electrical Systems

Electricity and Development

- To have a well developed economy, energy consumption must also be high.
  - Expands businesses and job opportunities
  - Aids food production and preservation
  - Education
  - Health
- The ten highest electrical power users per person are: Iceland, Norway, Kuwait, Canada, Finland, Sweden, United Arab Emirates, Luxembourg, United States, and Australia.
- These are amongst the richest countries in the world.

The Engineer and Electricity

- **The scientist** is concerned with what happens in an electric system and seeks to explain its mysteries.
- **The engineer** accepts that electricity is there and seeks to make use of its properties without the need to fully understand them.
- **Electrical engineering** could be summarized into four categories:
    1. The production of electrical energy.
    2. The transmission of electrical energy.
    3. The application of electrical energy.
    4. The control of electrical energy.

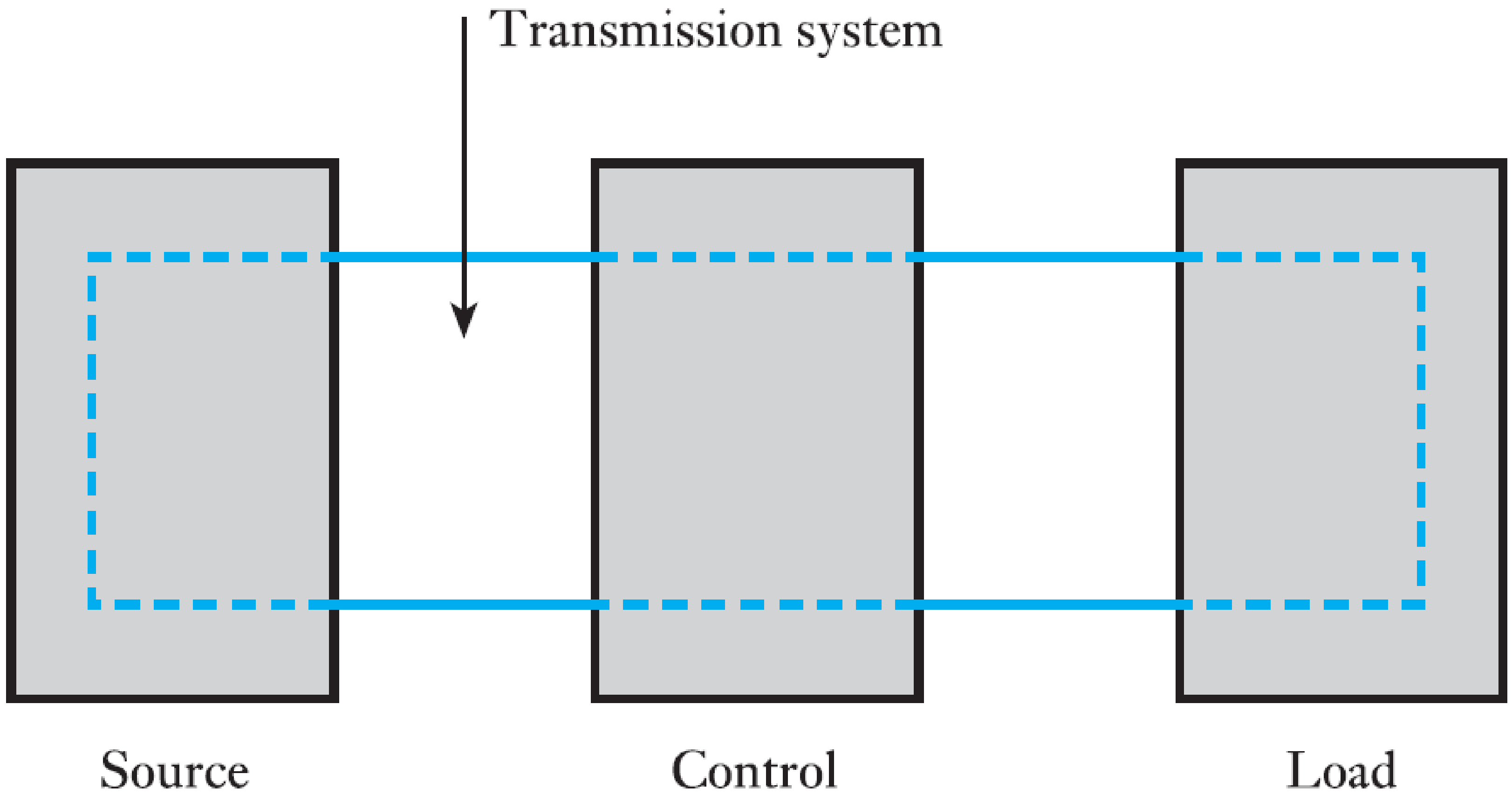
ELECTRICAL SYSTEM

- **Electricity** is a form of energy due to movement of charge
- **Electrical system** is A group of connected electrical components designed to carry out an operation
- The connected electrical components forms a circuit
- **Circuit** is Closed path formed by electrical components that allows the flow of electrons

Parts of an electrical system

- It has four constituents parts:
  - ✓Source
  - ✓Load
  - ✓The transmission system.
  - ✓The control apparatus.

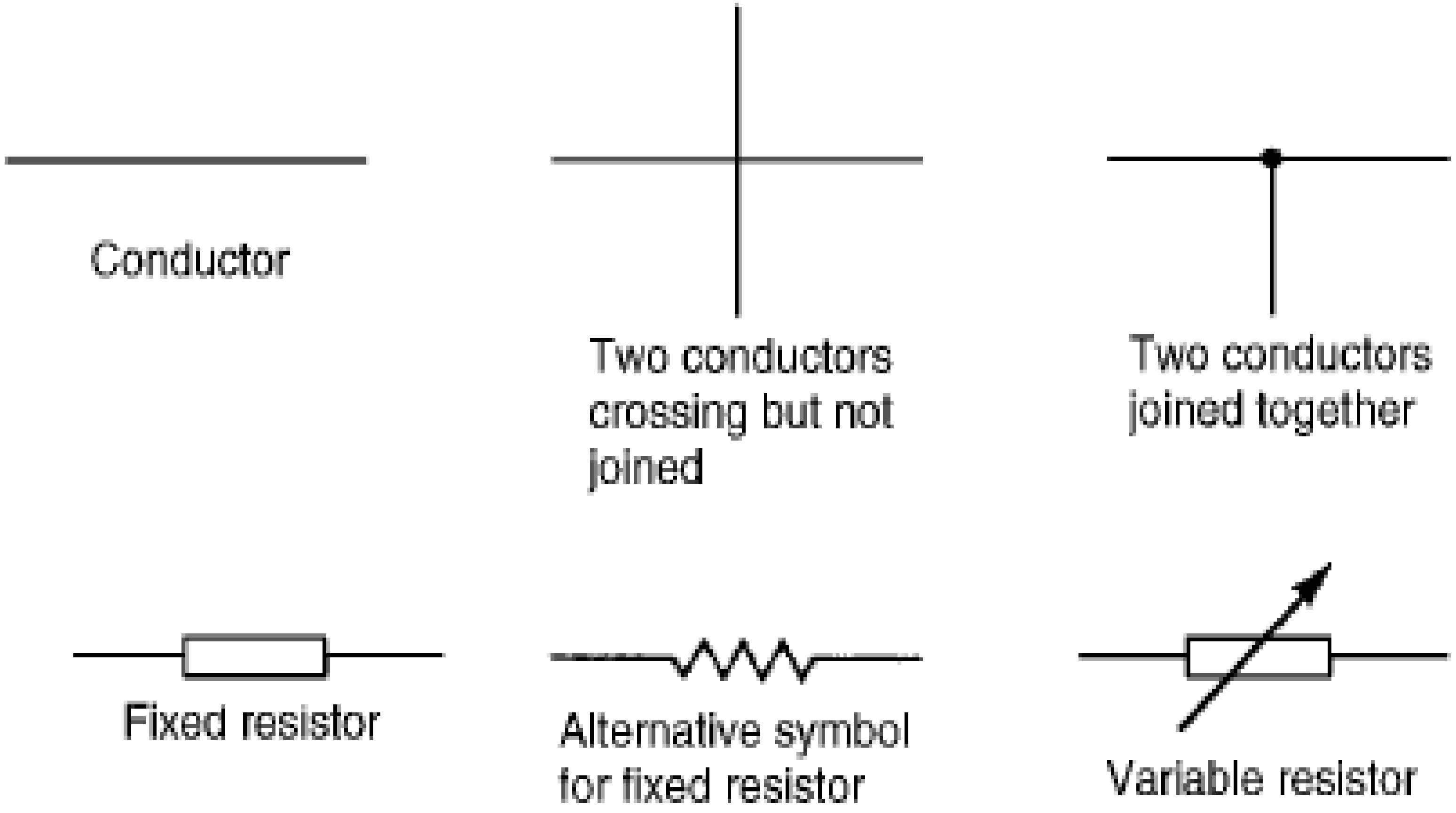
Parts of an electrical system



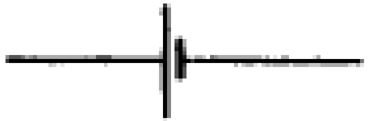
Parts of an electrical system

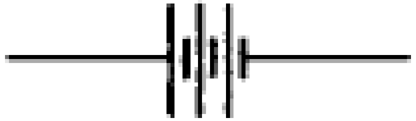
- **Source**: provides energy for the electrical system e.g. a battery, The socket outlet can also be thought as a source
- **Load:** consumes energy produced by the source e.g bulb, element heater
- **Transmission system:** conducts energy from source to load e.g. insulated wire
- **Control system**: controls the flow of energy between load and source

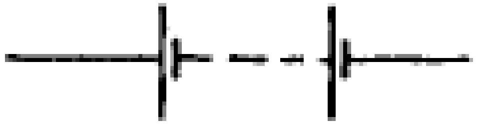
Standard symbols for electrical components

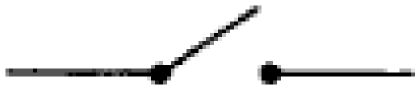


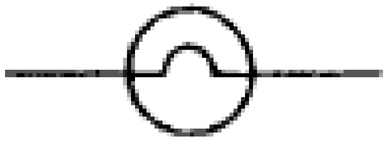
Standard symbols for electrical components… cont’d…


Cell

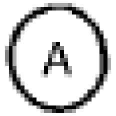

Battery of 3 cells


Alternative symbol for battery

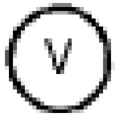

Switch


Filament lamp

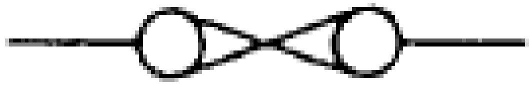

Fuse



Ammeter

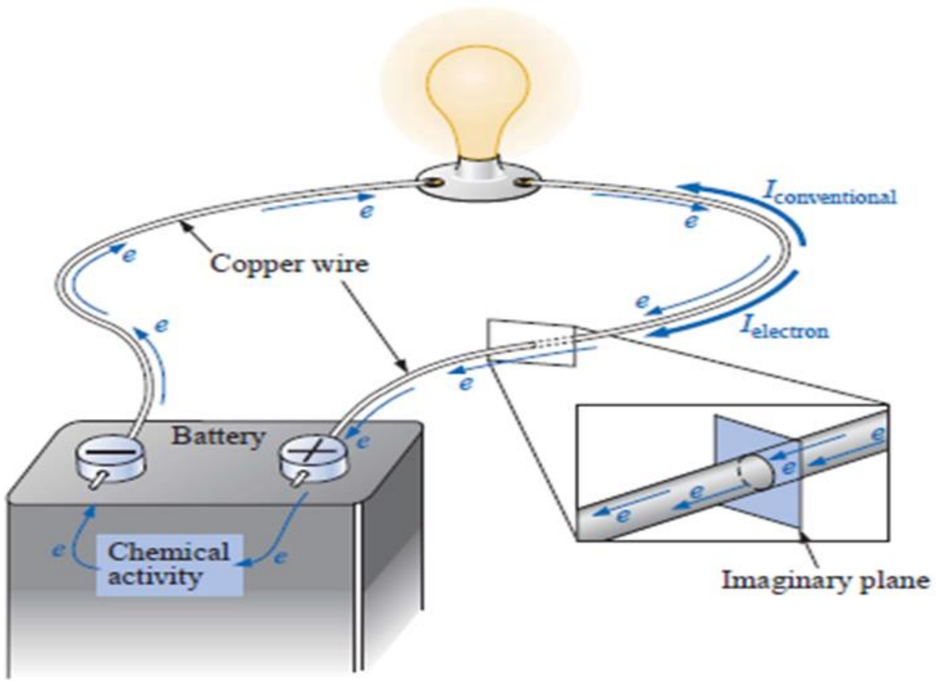


Voltmeter


Alternative fuse symbol

Simple lamp system

- Identify the parts of this simple lamp system?



Electric current

- All atoms consist of protons, neutrons and electrons.
- The protons, which have positive electrical charges, and the neutrons, which have no electrical charge, are contained within the nucleus.
- When there are more than two electrons in an atom the electrons are arranged into shells at various distances from the nucleus.

Electric current

- Electrons in the outer shell of an atom, are attracted to their nucleus less powerfully than are electrons whose shells are nearer the nucleus.
- What happens if an atom loses an electron?
  - ➢the atom is now called an **ion**
  - ➢The atom becomes positively charged
  - ➢The atom now is able to attract an electron to itself from another atom.
- Electricity is due to the movement of electric charge
- Electric charge is the excess of negative or positive electricity on a body or in space.
- If the excess is negative, the body is said to have a negative charge and vice versa

Electric current

- Electrons that move from one atom to another are called free electrons.
- If an electric pressure or **voltage** is applied across any material there is a tendency for electrons to move in a particular direction.
- This movement of free electrons, known as **drift**, constitutes an electric current flow.
- **Thus current is the rate of movement of charge**.

Current flow in a circuit

- The following conditions must be fulfilled for current to flow
    - ✓There must be a complete circuit around which the electrons should move
    - ✓There must be a driving movement to cause continuous flow of electrons. This achieved by a source(from high potential to low potential)

- The driving influence of current is termed the electromotive force (e.m.f)
- **Current** is the rate of flow of charge through a section of the circuit.

Electric current

- **Conductors** are materials that contain electrons that are loosely connected to the nucleus and can easily move through the material from one atom to another.
  - ✓e.g. copper, aluminum, silver

- **Insulators** are materials whose electrons are held firmly to their nucleus and does not readily permit electron flow.
  - ✓ e.g. porcelain, nylon, rubber

Electric current

- **Current Symbol: I** **Unit: ampere (A)**

Potential difference

- **Potential difference** (p.d.) is the difference of potential between two points of a conductor
- change in electric potential between two points in a circuit
- The energy transferred due to the passage of unit charge between two points in a circuit is termed the **potential difference**

Potential difference

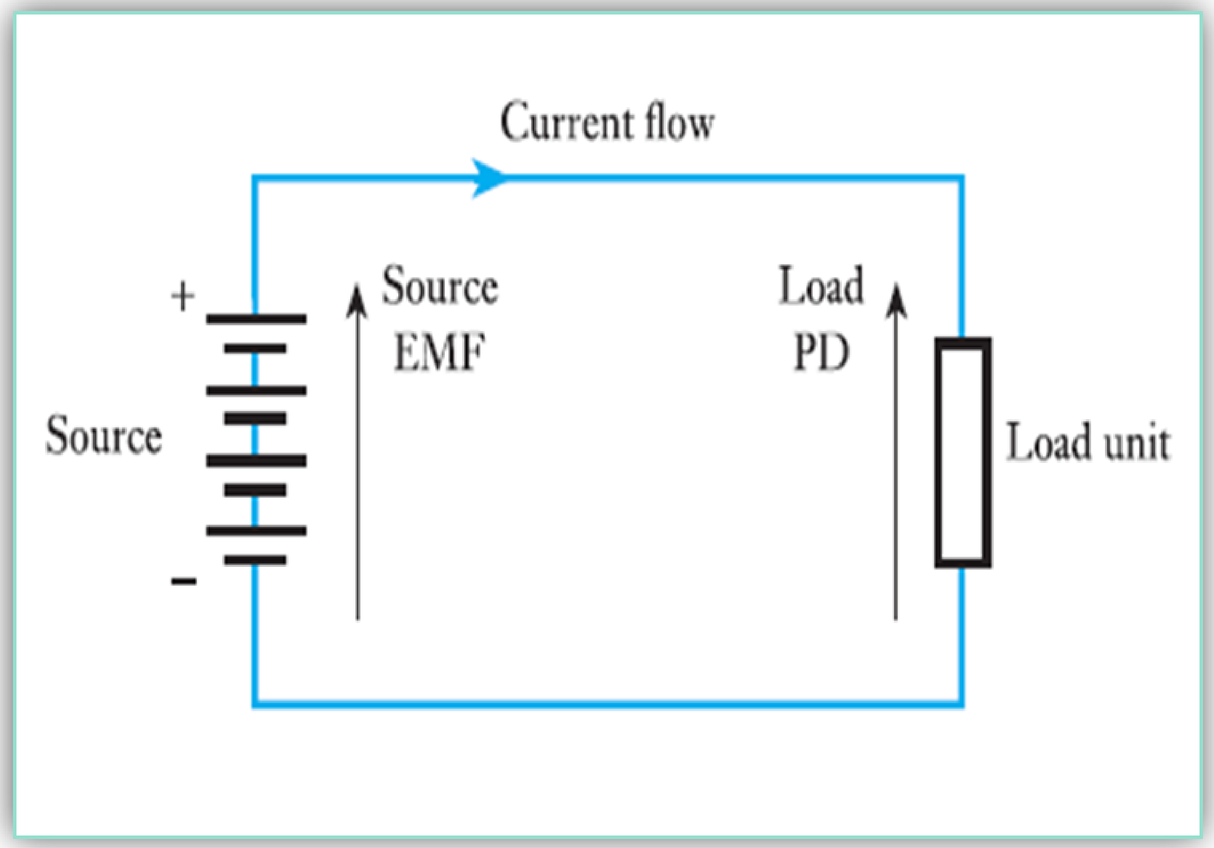
- The term **voltage** is a synonym for **potential difference** irrespective of the unit in which it is expressed.
- **Electric potential** Symbol: **V**   Unit: **volt (V)**
  - ✓Because p.d's are measured in volts, they are also referred to as voltage drops or voltages.

Electromotive force (e.m.f.)

- Electromotive force is a source of energy that can cause a current to flow in an electrical circuit or device.
- Symbol: ***E*** Unit: **volt (V)**

- The principal sources of e.m.f. are batteries and electric generators.
- both e.m.f. and p.d. are similar quantities. However,an e.m.f. is always active in that it tends to produce an electric current in a circuit whereas a p.d. may be either passive or active.

EMF And Potential Difference



Quantity of electricity

- The unit of quantity of electrical charge Q is the coulomb, C.
- It is the quantity of electricity passing a given point in a circuit when a current of 1 ampere is maintained for 1 second.
- Hence Q [coulombs] = I [amperes] × t [seconds],

$$\mathbf{Q = It}$$

- **Charge** Symbol: **Q** Unit: **coulomb (C)**

Quantity of electricity

Examples:

1. What current must flow if 0.24 coulombs is to be transferred in 15 ms?
2. If a current of 10 A flows for four minutes, find the quantity of electricity transferred.
3. If a charge of 25 C passes a given point in a circuit in a time of 125 ms, determine the current in the circuit.

Quantity of electricity

Example:

What current must flow if 0.24 coulombs is to be transferred in 15 ms?

Solution

Since the quantity of electricity, $Q = It$, then

$$I = \frac{Q}{t} = \frac{0.24}{15 \times 10^{-3}} = \frac{0.24 \times 10^3}{15} = \frac{240}{15} = \mathbf{16\ A}$$

Quantity of electricity

Example:

If a current of 10 A flows for four minutes, find the quantity of electricity transferred.

Solution

Quantity of electricity, $Q = It$ coulombs

$I = 10$ A; $t = 4 \times 60 = 240$ s

Hence $Q = 10 \times 240 = \mathbf{2400\ C}$

Quantity of electricity

1. If a charge of 25 C passes a given point in a circuit in a time of 125 ms, determine the current in the circuit.

$$Q = It$$

$$I = \frac{Q}{t} = \frac{25}{125 \times 10^{-3}} = 200\ \text{A}$$

- An electron carries charge of equivalent to -1.602×10^{-19} C
- The coulomb is a large unit for charges. In 1 C of charge, there are $\frac{1}{1.602 \times 10^{-19}} = 6.24 \times 10^{18}$ electrons

- How much charge is represented by 4600 electrons?

Resistance

- Resistance is the opposition to the flow of current.
- The symbol for resistance is R
- It is measured in ohms (Ω).

Ohm’s Law

- **Ohm’s law** states that the current I flowing in a circuit is directly proportional to the applied voltage V and inversely proportional to the resistance R, provided the temperature remains constant.
- Thus,

$$I = \frac{V}{R} \text{ or } V = IR \text{ or } R = \frac{V}{I}$$

Power

- It is the rate of doing work or the rate of energy conversion
- The symbol of power is **P**
- The unit of power is **watt(W)**
- **P=W/t** where W is work(energy)

Resistance (Power and energy)

If V represents the p.d., in volts, across a circuit having resistance R, in ohms, carrying a current I, in amperes, for time t, in seconds,

$$\boxed{V = IR}$$

or

$$I = \frac{V}{R}$$

Power $\boxed{P = IV = I^2R}$

$$= \frac{V^2}{R}$$

Also, the energy dissipated is given by

$$W = Pt = I^2Rt = IVt$$

Class exercise

PROVE THAT $V = W/Q$

Class exercise

$$V = \frac{P}{I} = \frac{W}{t} \cdot \frac{t}{Q}$$

$$\boxed{V = \frac{W}{Q}}$$

Example

- A CIRCUIT DELIVERS ENERGY AT THE RATE OF 20 W AND THE CURRENT IS 10 A. DETERMINE THE ENERGY OF EACH COULOMB OF CHARGE IN THE CIRCUIT

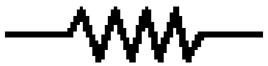
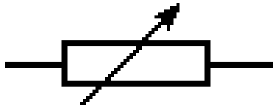
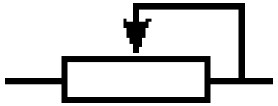
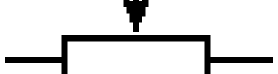
- A CURRENT OF 5 A flOWS IN A RESISTOR OF RESISTANCE 8 Ω. DETERMINE THE RATE OF HEAT DISSIPATION AND ALSO THE HEAT DISSIPATED IN 30 S.

EXAMPLE

A MOTOR GIVES AN OUTPUT POWER OF 20 KW AND OPERATES WITH AN EFFiCIENCY OF 80 PER CENT. IF THE CONSTANT INPUT VOLTAGE TO THE MOTOR IS 200 V, WHAT IS THE CONSTANT SUPPLY CURRENT?

Resistors

- A resistor is a device which provides resistance in an electrical circuit.
- The resistance of a resistor is said to be linear if the current through the resistor is proportional to the p.d. across its terminals.

Symbol	Representing
	Fixed resistor
	Resistor symbol found in old diagrams, no longer used
 or 	Variable resistor (or rheostat)
	Potentiometer

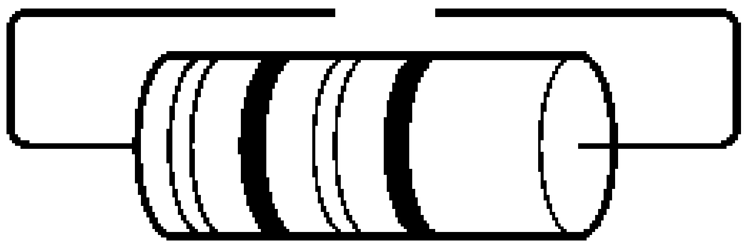
Resistors

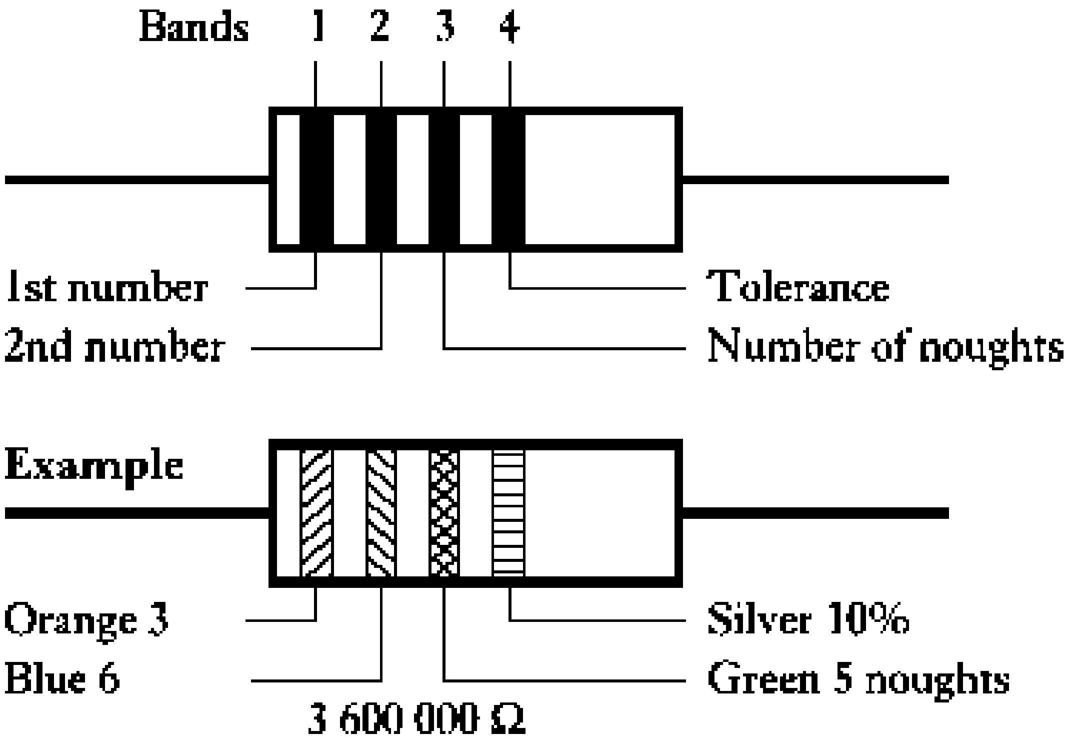
- **Variable resistors** (potentiometers) can provide an infinite number of resistance values between zero and their maximum value.
- **Fixed resistors** have only one single value of resistance and can be classified as:
  - ➢**Carbon Composition Resisto**r – Made of carbon dust or graphite paste, low wattage values
  - ➢**Film or Cermet Resistor** – Made from conductive metal oxide paste, very low wattage values
  - ➢**Wire-wound Resistor** – Metallic bodies for heatsink mounting, very high wattage ratings

Standard values of available resistors

Ohms (Ω)					Kilohms (kΩ)		Megohms (MΩ)	
0.10	1.0	10	100	1000	10	100	1.0	10.0
0.11	1.1	11	110	1100	11	110	1.1	11.0
0.12	1.2	12	120	1200	12	120	1.2	12.0
0.13	1.3	13	130	1300	13	130	1.3	13.0
0.15	1.5	15	150	1500	15	150	1.5	15.0
0.16	1.6	16	160	1600	16	160	1.6	16.0
0.18	1.8	18	180	1800	18	180	1.8	18.0
0.20	2.0	20	200	2000	20	200	2.0	20.0
0.22	2.2	22	220	2200	22	220	2.2	22.0
0.24	2.4	24	240	2400	24	240	2.4	
0.27	2.7	27	270	2700	27	270	2.7	
0.30	3.0	30	300	3000	30	300	3.0	
0.33	3.3	33	330	3300	33	330	3.3	
0.36	3.6	36	360	3600	36	360	3.6	
0.39	3.9	39	390	3900	39	390	3.9	
0.43	4.3	43	430	4300	43	430	4.3	
0.47	4.7	47	470	4700	47	470	4.7	
0.51	5.1	51	510	5100	51	510	5.1	
0.56	5.6	56	560	5600	56	560	5.6	
0.62	6.2	62	620	6200	62	620	6.2	
0.68	6.8	68	680	6800	68	680	6.8	
0.75	7.5	75	750	7500	75	750	7.5	
0.82	8.2	82	820	8200	82	820	8.2	
0.91	9.1	91	910	9100	91	910	9.1	

Resistor Coding





Digit	Colour
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White
Tolerance	**Colour**
5%	Gold
10%	Silver
20%	No colour band

Resistor Marking

A letter code is used for resistors that are very small or complex shape so that the colour coding is difficult to apply. E.g the metal-oxide resistors.

Resistance	Marking
0.47 Ω	R47
4.7 Ω	4R7
47 Ω	47R
470 Ω	470R
4.7 kΩ	4K7
47 kΩ	47K
4.7 MΩ	4M7

Example:

- **A resistor is marked as follows:**

  1st band Brown

  2nd band Black

  3rd band Orange

  No other band

- **What is its resistance and between what values does it lie?**

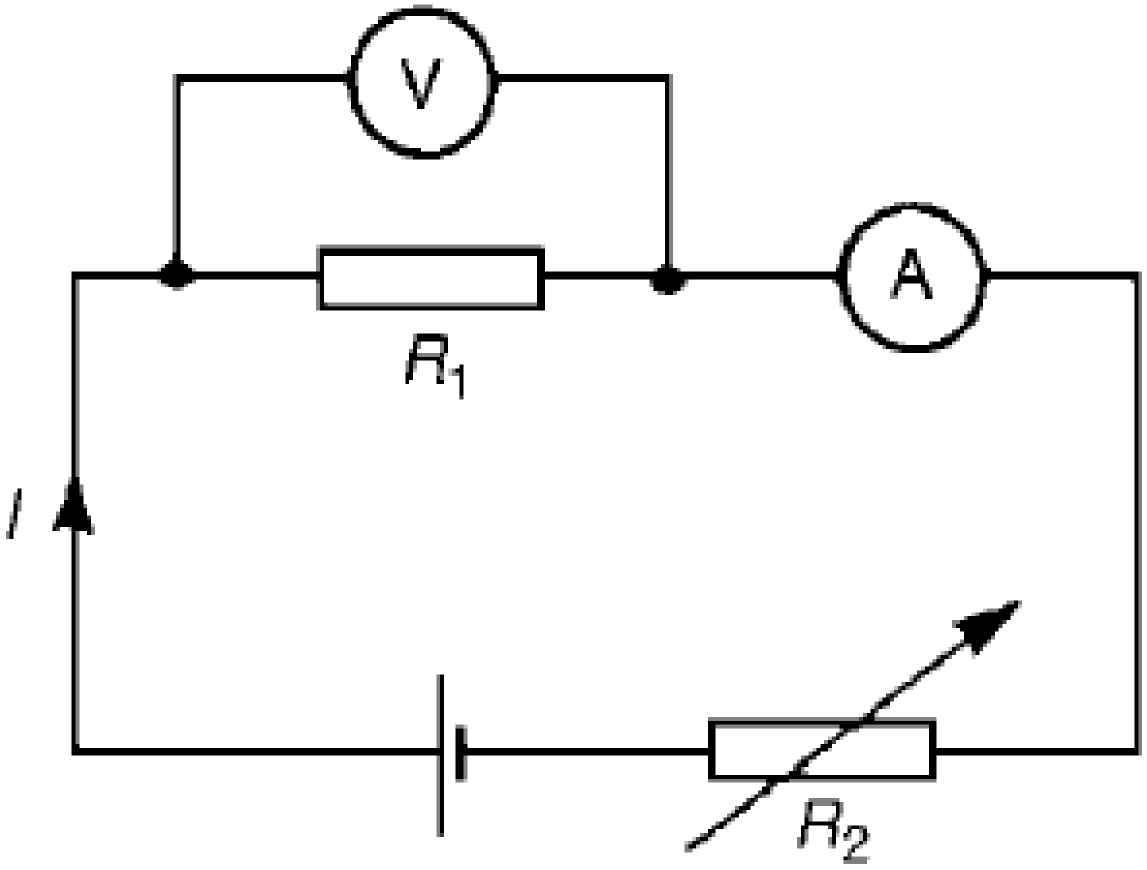
Solution

- ✓Brown (1) = 1 first unit, Black (0) = 0 second unit, Orange (3) = 000 number of zeros
- ✓10000 = 10 kΩ
- ✓Since no further band is given the tolerance is ±20 per cent. The resistance lies between 10 000 + 2000 and 10 000 − 2000, i.e. 12 kΩ and 8 kΩ.

Basic electrical measuring instruments

- An **ammeter** is an instrument used to measure current.
  - ✓it must be connected **in series** with the circuit.
  - ✓it must have a very **low resistance** Since all the current in the circuit passes through the ammeter
- A **voltmeter** is an instrument used to measure p.d.
  - ✓it must be connected **in parallel** with the part of the circuit whose p.d. is required.
  - ✓must have a very **high resistance** To avoid a significant current flowing through it a voltmeter

Basic electrical measuring instruments



Basic electrical measuring instruments

- An **ohmmeter** is an instrument for measuring resistance.
- A **multimeter**, or universal instrument, may be used to measure voltage, current and resistance.
- The **cathode ray oscilloscope (CRO)** may be used to observe waveforms and to measure voltages and currents.

Power and energy

$$\textbf{Electrical energy} = \textbf{power} \times \textbf{time}$$

- If the power is measured in watts and the time in seconds then the unit of energy is watt-seconds or **joules**.
- If the power is measured in kilowatts and the time in hours then the unit of energy is **kilowatt-hours**, often called the '**unit of electricity**'.
- The 'electricity meter' in the home records the number of kilowatt-hours used and is thus an energy meter.

Power and energy

Example

1. Electrical equipment in an office takes a current of 13 A from a 240V supply. Estimate the cost per week of electricity if the equipment is used for 30 hours each week and 1 kWh of energy costs 80 kwacha.

More examples

1. A 100 V battery is connected across a resistor and causes a current of 5 mA to flow. Determine the resistance of the resistor. If the voltage is now reduced to 25 V, what will be the new value of the current flowing?
2. A current of 5 A flows in the winding of an electric motor, the resistance of the winding being 100 ohms. Determine (a) the p.d. across the winding, and (b) the power dissipated by the coil.
3. A business uses two 3 kW fires for an average of 20 hours each per week, and six 150 W lights for 30 hours each per week. If the cost of electricity is 81.5 kwacha per unit, determine the monthly cost of electricity to the business. (Assume 1 month = 4 weeks).

More examples

1. A 100 V battery is connected across a resistor and causes a current of 5 mA to flow. Determine the resistance of the resistor. If the voltage is now reduced to 25 V, what will be the new value of the current flowing?

Solution

$$\text{Resistance } R = \frac{V}{I} = \frac{100}{5 \times 10^{-3}} = \frac{100 \times 10^3}{5}$$

$$= 20 \times 10^3 = \mathbf{20\,k\Omega}$$

Current when voltage is reduced to 25 V,

$$I = \frac{V}{R} = \frac{25}{20 \times 10^3} = \frac{25}{20} \times 10^{-3} = \mathbf{1.25\,mA}$$