Electricity

10th Class

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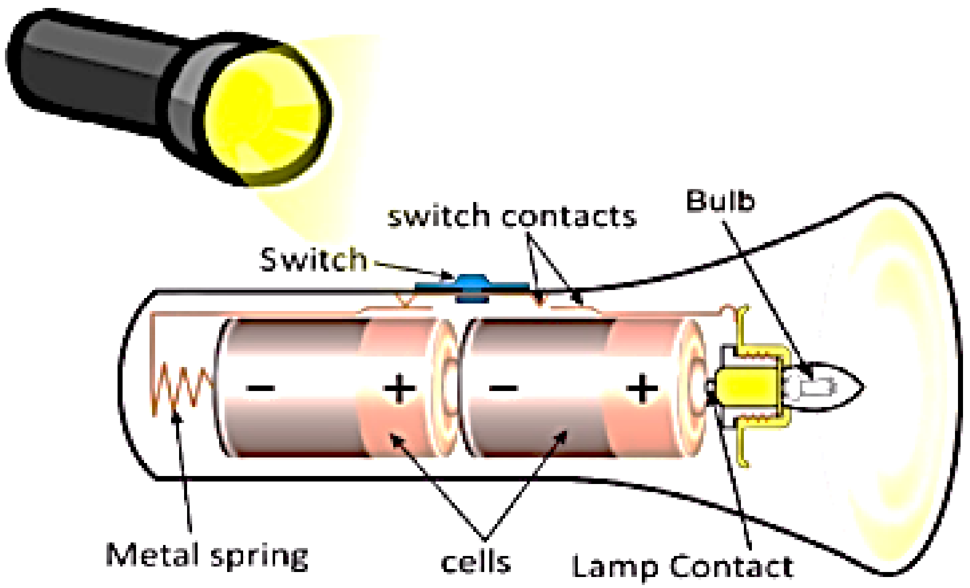
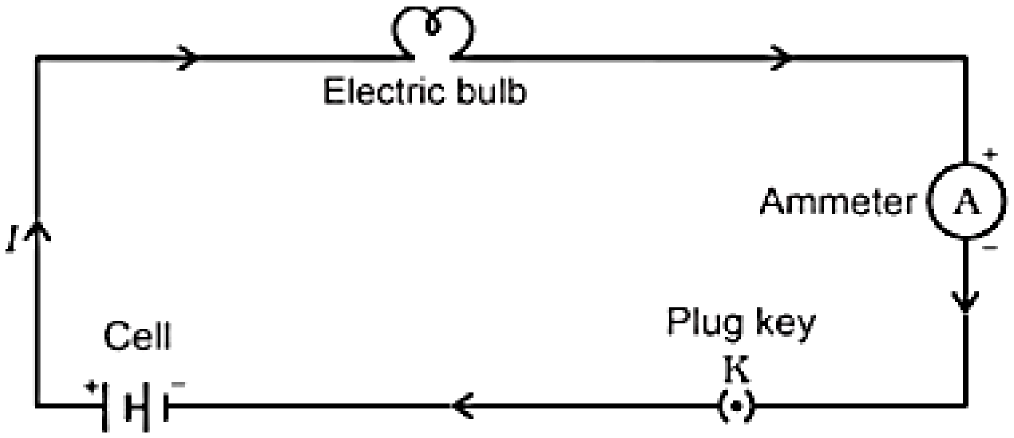
ELECTRIC CURRENT AND CIRCUIT

- Flow of electric charges through a conductor (e.g., metallic wire) is called an **electric current.**
- In a torch, the cells (or a battery, when placed in proper order) provide electric current through the bulb to glow.
- A continuous and closed path of an electric current is called **electric circuit.** If the circuit is broken (or the switch is turned off), the current stops.
- Electric current is measured as the amount of charge flowing through a particular area in unit time. i.e., it is the **rate of flow of electric charges.**

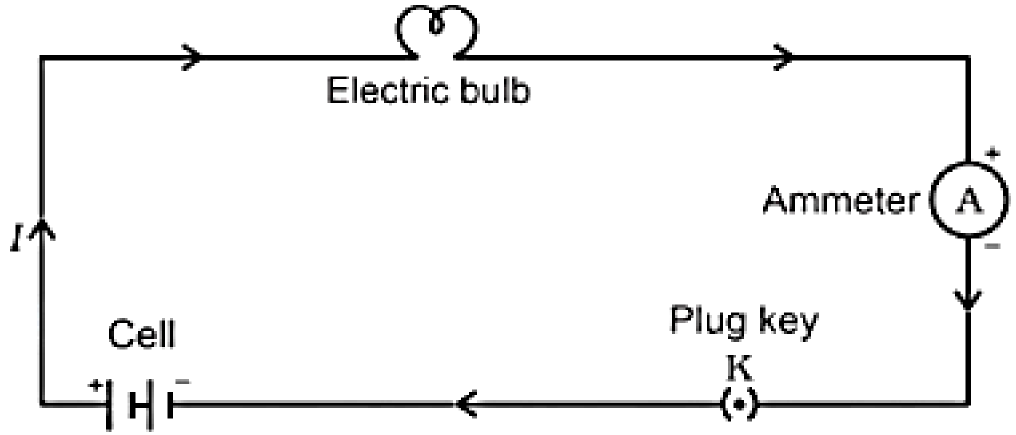




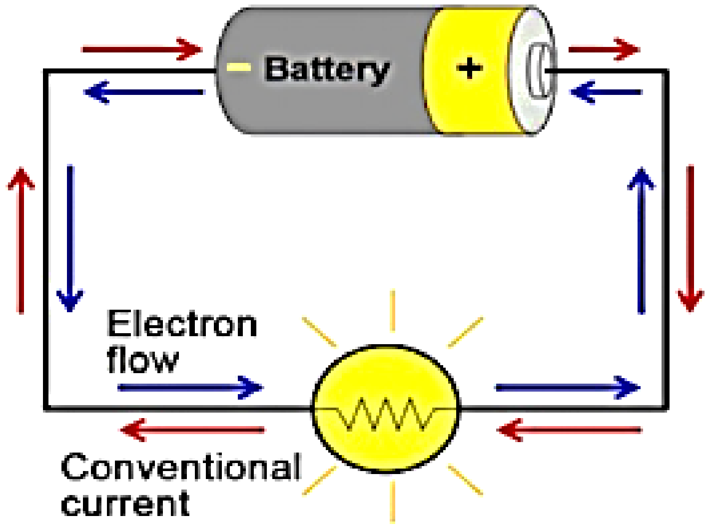
A schematic diagram of an electric circuit

ELECTRIC CURRENT AND CIRCUIT

- In a circuit of metallic wire, **electrons** constitute the flow of charges. Electrons were unknown during the discovery of electricity. So, electric current was considered as the flow of positive charges and their direction of flow was taken as the direction of electric current.
- Conventionally, in an electric circuit, the direction of **electric current is taken as opposite to the direction of the flow of electrons** (negative charges). i.e., electric current flows from positive terminal of the cell to negative terminal.



A schematic diagram of an electric circuit

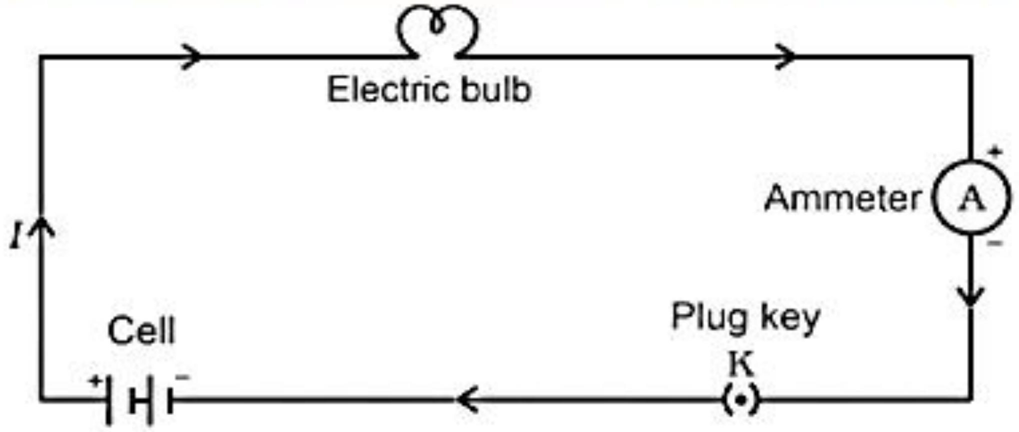


ELECTRIC CURRENT AND CIRCUIT

- Consider a **net charge *Q*** flows across a cross-section of a conductor in **time *t***. Then, **current *I*** through the cross-section is

$$I = \frac{Q}{t} \quad \text{or} \quad Q = It$$

- **SI unit** of electric charge is **coulomb (C).** It is equivalent to the charge contained in $\mathbf{6 \times 10^{18}}$ **electrons.** i.e., an electron has a negative charge of $\mathbf{1.6 \times 10^{-19}}$ **C.**
- SI unit of electric current is **ampere (A),** named after **Andre-Marie Ampere** (France, 1775–1836).

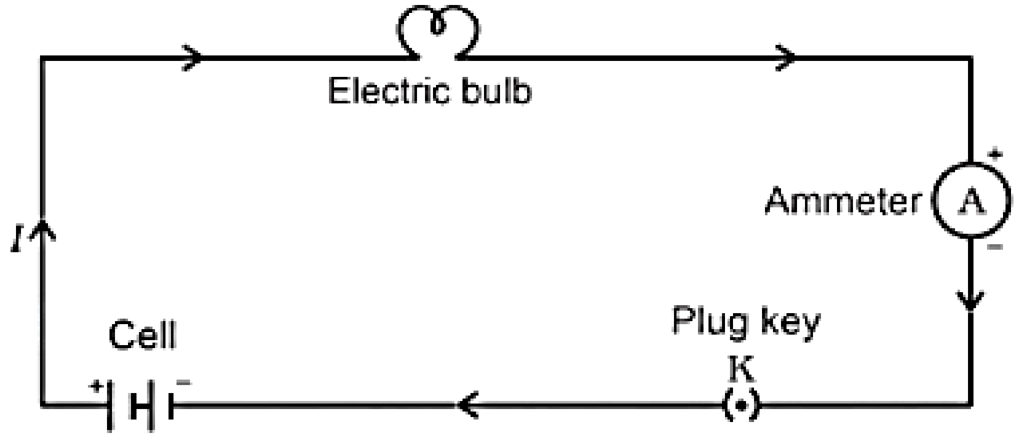


A schematic diagram of an electric circuit

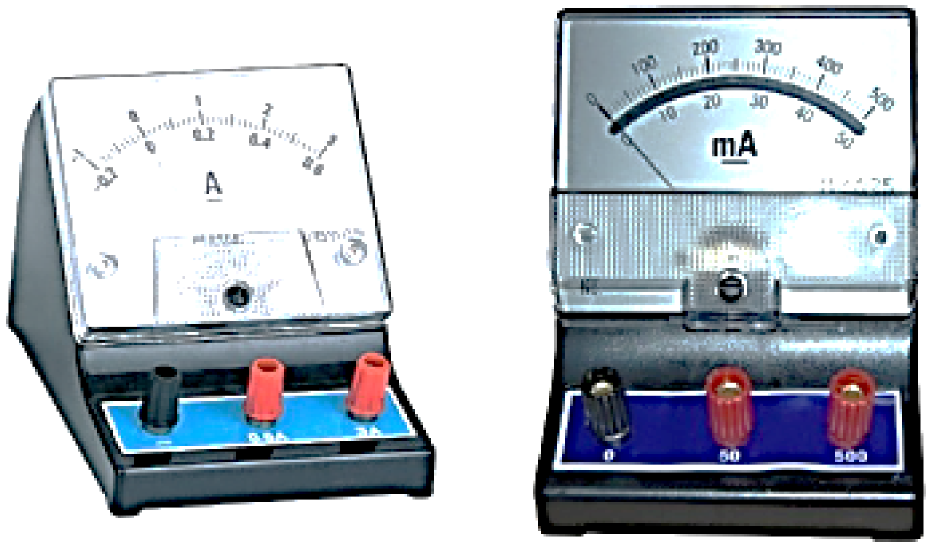
Andre-Marie Ampere

ELECTRIC CURRENT AND CIRCUIT

- **One ampere** represents the flow of one coulomb of charge per second, i.e., **1 A = 1 C/1 s.**
- Small quantities of current are expressed in **milliampere (1 mA = 10^{-3} A)** or in **microampere (1 μA = 10^{-6} A).**
- **Ammeter:** An instrument **to measure electric current** in a circuit. It is always connected in series in a circuit.



A schematic diagram of an electric circuit



ELECTRIC CURRENT AND CIRCUIT

Problem

A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.

Solution

$I = 0.5$ A; $t = 10$ min = 600 s.

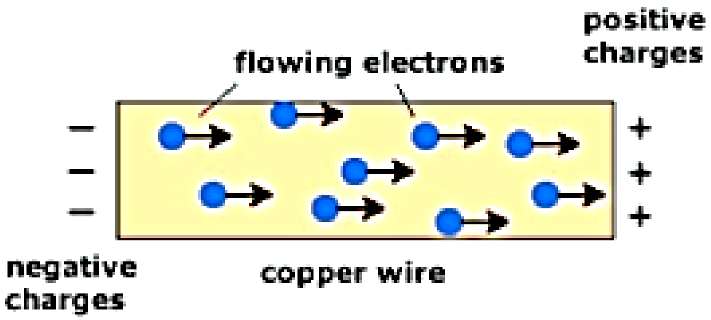
$Q = It$

= 0.5 A × 600 s

= **300 C**

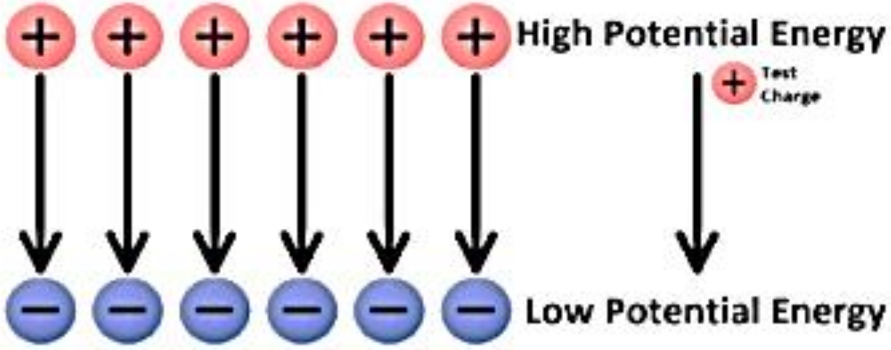
'Flow' of charges inside a wire

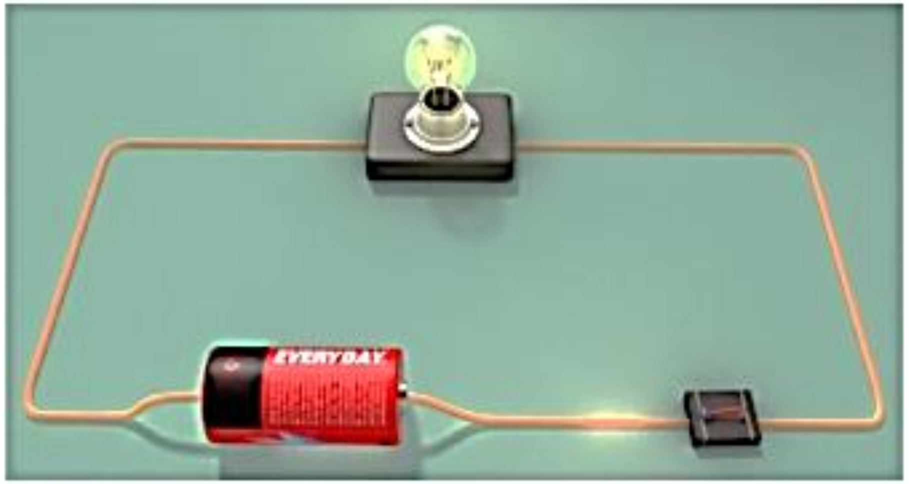
- Inside a solid conductor, atoms are packed together. But electrons can easily travel through it, almost as if they are in a vacuum.
- When a current flows through a conductor, the electrons move with an average 'drift speed' (1 mm s^{-1} for a typical copper wire). However, an electric bulb lights up as soon as the switch is turn on. It is not due to the movement of an electron from one terminal to the other terminal through the bulb.



ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

- Electric charges do not flow in a metallic conductor (e.g. copper wire) by themselves. Here, **gravity has no role.**
- Electrons move only if there is a **difference of electric pressure** in conductor. It is called **potential difference.**
- The chemical action within a **cell/battery** can generate the potential difference across the terminals of the cell, even when no current is drawn from it.
- When the cell is connected to a conducting circuit, the potential difference sets the charges in motion and produces an electric current. To maintain this current, the cell has to expend chemical energy stored in it.





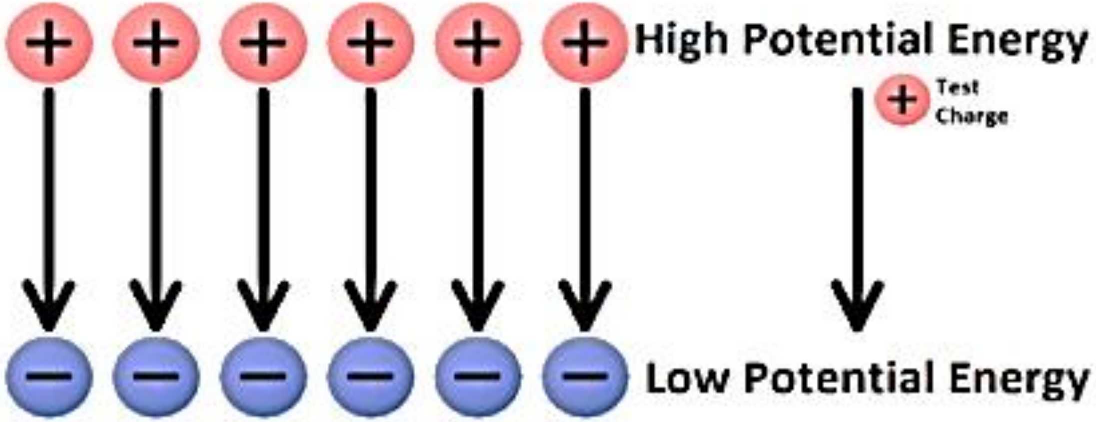
ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

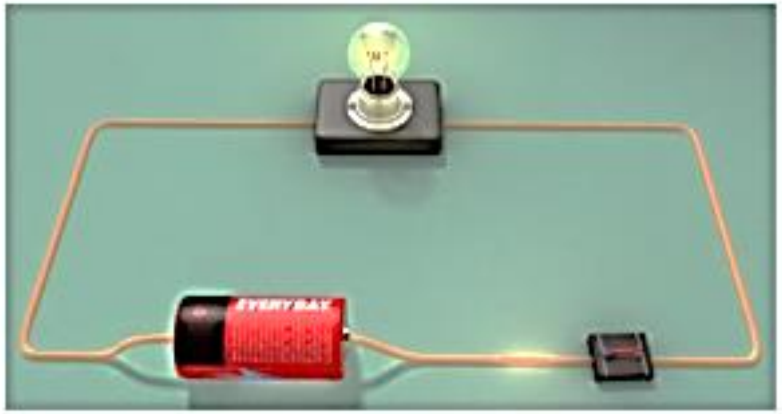
- The **electric potential difference** between two points in an electric circuit is the work done to move a unit charge from one point to the other.

Potential difference *(V)* between two points = **Work done *(W)*/Charge *(Q)*.**

$V = W/Q$ or $W = VQ$

- SI unit of potential difference is **volt (V),** named after **Alessandro Volta** (Italy, 1745–1827).





ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

One volt is the **potential difference** between two points in a current carrying conductor when **1 joule of work** is done to move **1 coulomb charge** from one point to other.

Therefore, $1 \text{ volt} = \dfrac{1 \text{ joule}}{1 \text{ coulomb}}$ or $1 \text{ V} = 1 \text{ J C}^{-1}$

Voltmeter: Instrument to measure potential difference. It is always connected in parallel across points between which the potential difference is to be measured.

Problem

How much work is done in moving a charge of 2 C across two points having a potential difference 12 V?

Solution

Amount of charge Q = 2 C.

Potential difference V = 12 V.

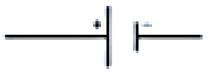
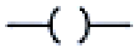
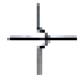
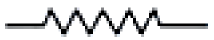
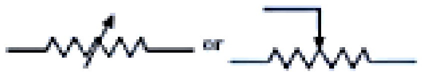
Amount of work $W = VQ$.

= 12 V × 2 C

= 24 J.

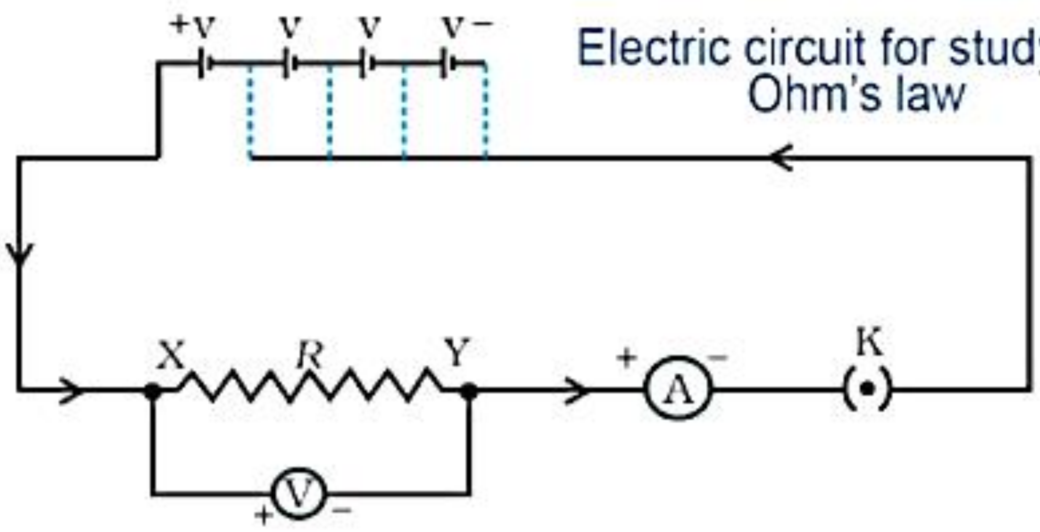
CIRCUIT DIAGRAM

Conventional symbols of some commonly used components in circuit diagrams

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	
8	A resistor of resistance R	
9	Variable resistance or rheostat	
10	Ammeter	
11	Voltmeter	

OHM'S LAW

- Set up a circuit consisting of a nichrome wire XY (0.5 m length), an ammeter, a voltmeter and four cells of 1.5 V each. (Nichrome = an alloy of Ni, Cr, Mn & Fe.)
- Using one cell, note the ammeter reading I for the current and voltmeter reading V for potential difference across the nichrome wire. Repeat this using 2, 3 & 4 cells.



Electric circuit for studying Ohm's law

Number of cells used	Current through the nichrome wire, I (ampere)	Potential difference across nichrome wire, V (volt)	V/I (volt/ ampere)
1	0.5	1.5	3
2	1.0	3.0	3
3	1.5	4.5	3
4	2.0	6.0	3

OHM'S LAW

- In each case, ***V/I* value** is approximately the **same.**
- ***V–I* graph** is a straight line. Thus, ***V/I*** is a constant ratio.

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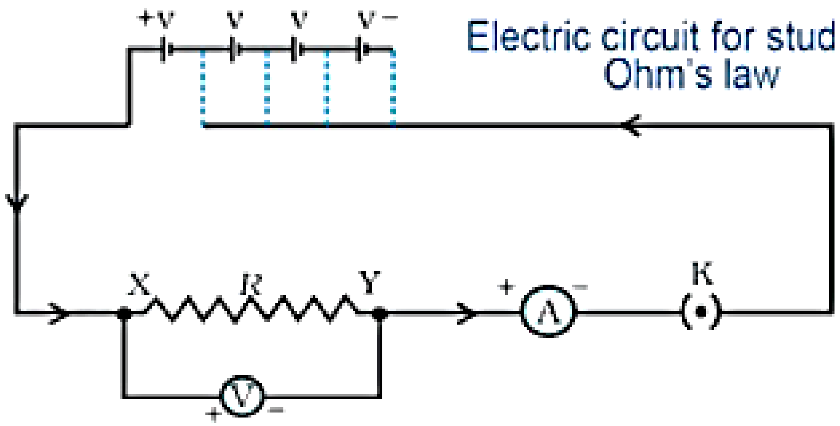
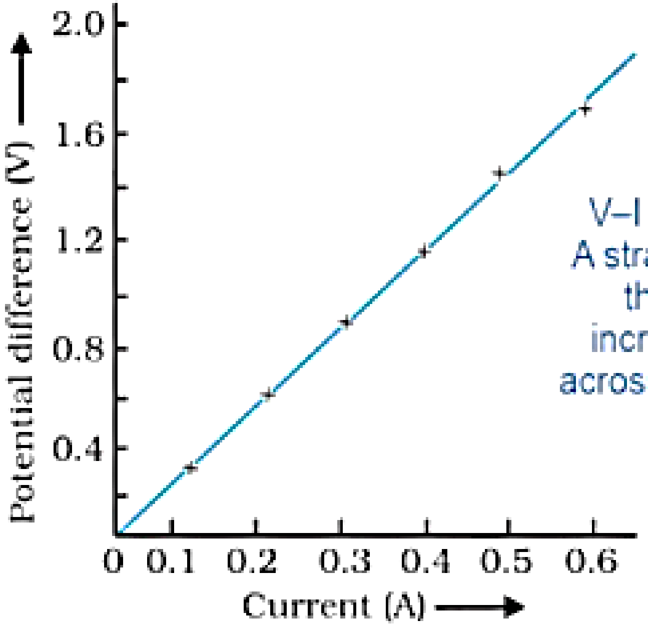


Electric circuit for studying Ohm's law



V–I graph for a nichrome wire. A straight-line plot shows that as the current through a wire increases, potential difference across the wire increases linearly- this is Ohm's law.

OHM'S LAW

- In 1827, **Georg Simon Ohm** (Germany, 1787–1854) found out relationship between current and the potential difference.
- **Potential difference *(V)*** across the ends of a metallic wire in an electric circuit is directly proportional to the **current *I*** flowing through it at constant temperature. It is called **Ohm's law.**

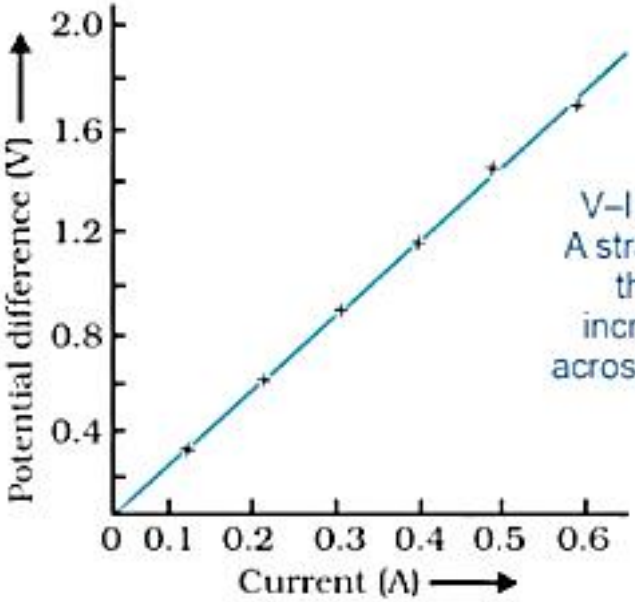
$$V \propto I$$

or V/I = constant = R

or $V = IR$

or $I = V/R$

Georg Simon Ohm



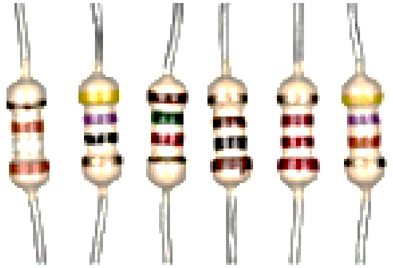
V–I graph for a nichrome wire. A straight-line plot shows that as the current through a wire increases, potential difference across the wire increases linearly- this is Ohm's law.

OHM'S LAW

- **R is a constant** for the given metallic wire at a given temperature and is called its **resistance.** It is the property of a conductor to resist the flow of charges. Its SI unit is **ohm (Ω).**
- According to Ohm's law, ***R = V/I***
- If the **potential difference** is **1 *V*** and the **current** is **1 *A*,** then the **resistance (R)** of the conductor is **1 Ω.**

$$1\ \text{ohm} = \frac{1\ \text{volt}}{1\ \text{ampere}}$$

- A conductor having appreciable resistance is called a **resistor.** It is used **to control electric current.**
- The current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved. It has many practical applications.
- A component used to regulate current without changing the voltage source is called **variable resistance. Rheostat** is a variable resistor used to change resistance.



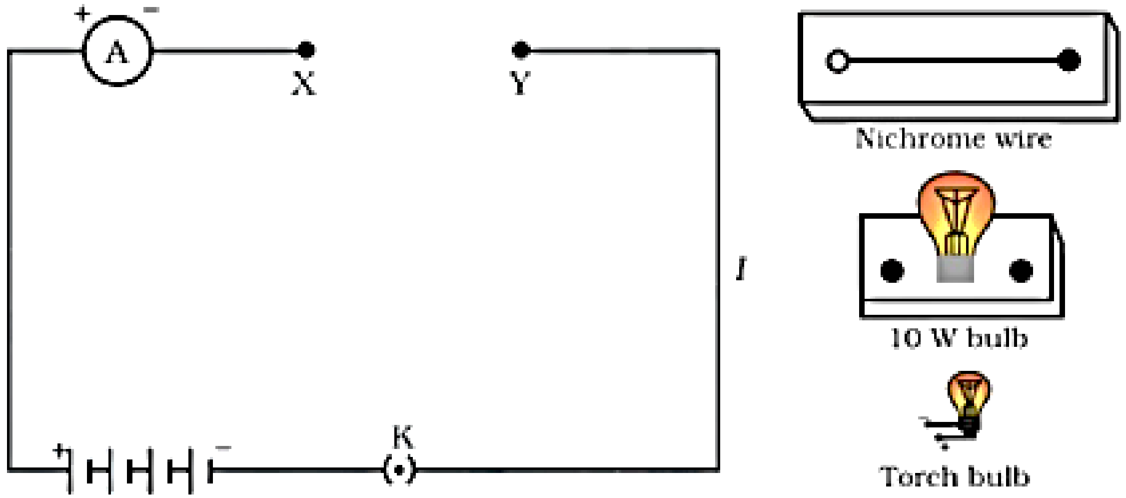
Resistors

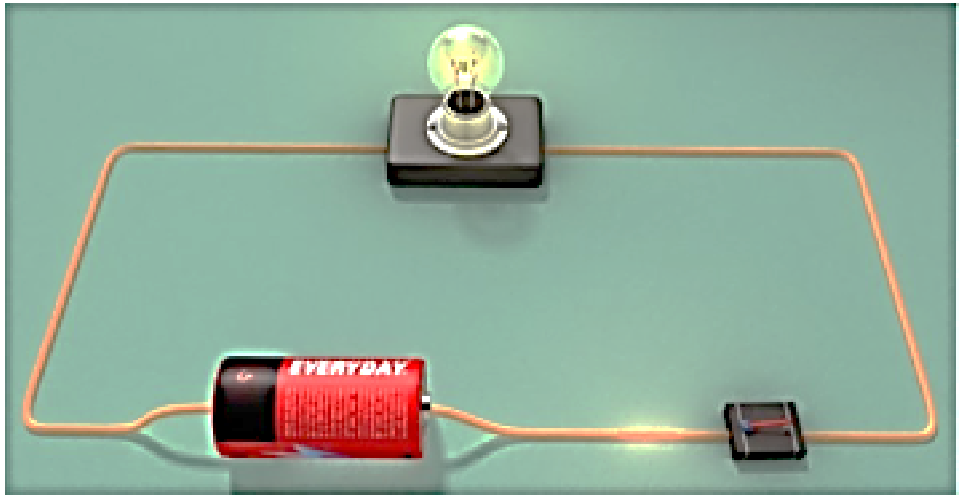
Rheostat

OHM'S LAW

Electrical resistance of a conductor

- Set up a circuit by connecting **four dry cells of 1.5 V** each in series with the **ammeter** (0 – 5 A range) leaving a **gap XY** in the circuit.
- Complete the circuit by connecting a **nichrome wire** in the gap XY. Plug the key. Note down ammeter reading.
- Replace the nichrome wire with a **torch bulb** in the circuit and note down the ammeter reading.
- Repeat this with a **10 W bulb** and any material.
- The current is different for different components. In certain components, there is easy flow of electric current while the others resist the flow.

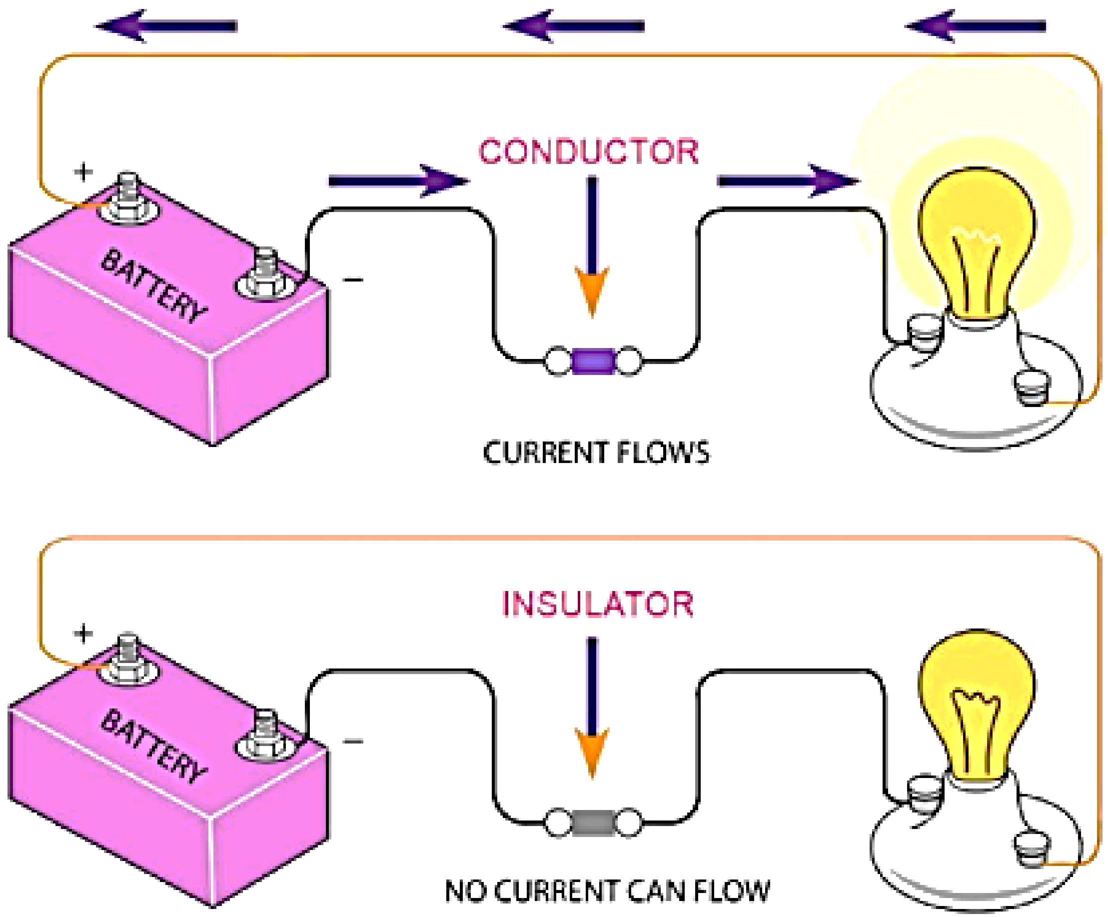




OHM'S LAW

Electrical resistance of a conductor

- Within a conductor, electrons are not completely free to move due to the attraction by atoms. So, resistance is increased and motion of electrons is retarded.
- A component that conducts electricity and has a low resistance is called a **good conductor.**
- A component with a high resistance is a **poor conductor.**
- A component with very high resistance is called an **insulator.** It does not conduct electricity.

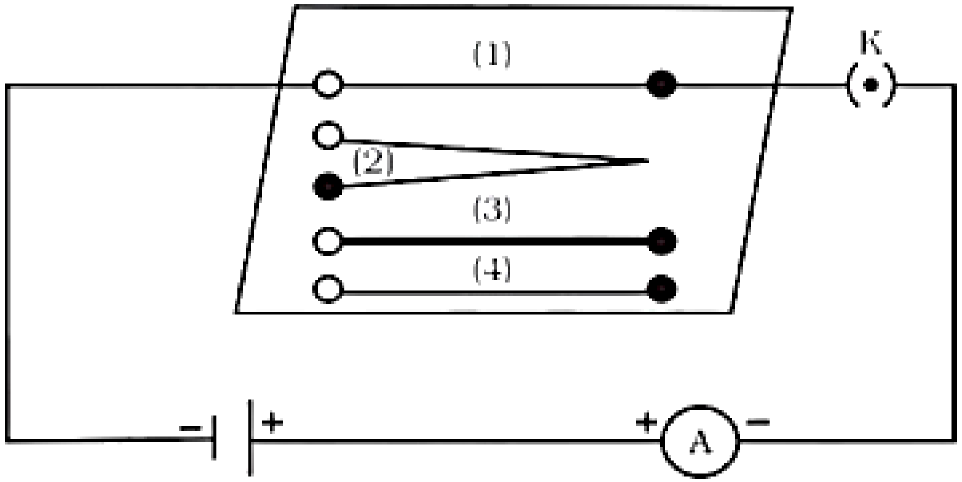


FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

Note the **ammeter reading** in an electric circuit with

1. A **nichrome wire** of **length *l*.** Assume the reading = **1 A.**
2. **Nichrome wire** of twice the length **(2*l*).** Here, ammeter reading decreases to one-half **(0.5 A).**
3. A **thicker** (larger cross-sectional area) **nichrome wire** of the same **length *l*.** Here, reading is increased. If the area is doubled, reading is also doubled **(2A).**
4. A **copper wire** of same length and cross-sectional area as that of first nichrome wire. Here, reading is changed.

Nichrome wire

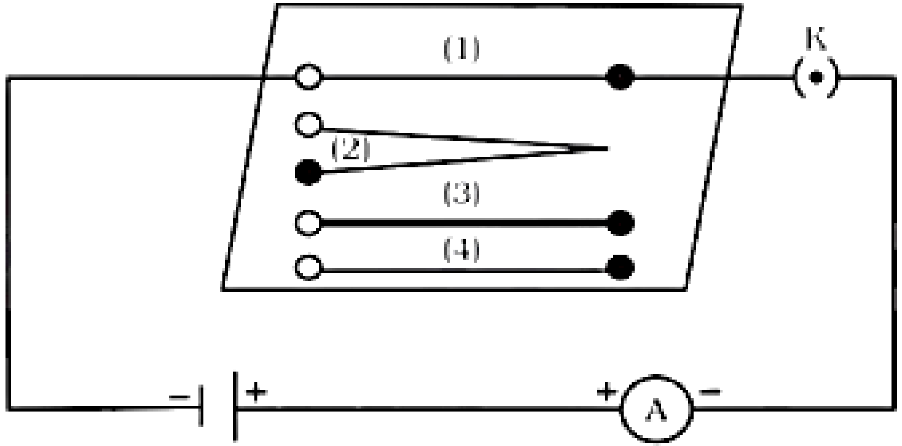


FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

- Thus, resistance of a conductor depends on
  - i. **Its length**
  - ii. **Its area of cross-section**
  - iii. **Nature of material.**
- Resistance of a uniform metallic conductor is directly proportional to its length (***R*** $\propto$ ***l***) and inversely proportional to the area of cross-section (***R*** $\propto$ ***1/A***). i.e.,

$$R \propto \frac{l}{A} \quad \text{or} \quad R = \rho \frac{l}{A}$$

- Where **ρ (rho)** is a **constant** of proportionality and is called **electrical resistivity** of the material of conductor. It is a characteristic property of the material.
- SI unit of resistivity is **Ω m.**



Nichrome wire, length *l*

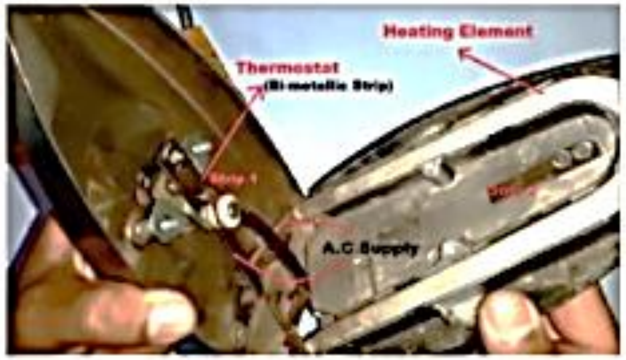
Nichrome wire, length 2 *l*

Nichrome wire, thicker

Copper wire, length *l*

FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

- **Resistivity of metals & alloys** is **very low (10^{-8}** to **10^{-6} Ω m).** They are **good conductors** of electricity.
- **Resistivity of insulators** (rubber, glass etc.) is **very high (10^{12}** to **10^{17} Ω m).**
- Resistance and resistivity vary with temperature.
- Resistivity of an **alloy** is generally higher than that of its constituent metals. Alloys do not oxidise (burn) readily at high temperatures. So, they are used in **electrical heating devices** like electric iron, toasters etc.
- **Tungsten** is used for filaments of electric bulbs. **Copper & aluminium** are used for electrical transmission lines.



FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

Electrical resistivity of some substances at 20°C

Material		Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (Cu + Ni)	49×10^{-6}
	Manganin (Cu + Mn + Ni)	44×10^{-6}
	Nichrome (Ni + Cr + Mn + Fe)	100×10^{-6}
Insulators	Glass	$10^{10} – 10^{14}$
	Hard rubber	$10^{13} – 10^{16}$
	Ebonite	$10^{15} – 10^{17}$
	Diamond	$10^{12} – 10^{13}$
	Paper (dry)	10^{12}

FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

Problem

a) How much current will an electric bulb draw from a 220 V source, if the resistance of bulb filament is 1200 Ω?

b) How much current will an electric heater draw from a 220 V source, if the resistance of heater coil is 100 Ω?

Solution

a) $V = 220$ V; $R = 1200$ Ω.

Current, $I = V/R = 220$ V/1200 Ω = **0.18 A.**

b) $V = 220$ V, $R = 100$ Ω.

Current, $I = 220$ V/100 Ω = **2.2 A.**

Thus the current drawn by an electric bulb and electric heater from same 220 V source is different.

Problem

Potential difference between the terminals of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is increased to 120 V?

Solution

Potential difference $V = 60$ V, current $I = 4$ A.

$R = V/I = (60\text{ V})/(4\text{ A}) =$ **15 Ω.**

When the potential difference is increased to 120 V

Current $I = V/R = (120\text{ V})/(15\ \Omega) =$ **8 A.**

FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

Problem

Resistance of a metal wire of length 1 m is 26 Ω at 20°C. If the diameter of the wire is 0.3 mm, what will be the resistivity of the metal at that temperature? Predict the material of the wire.

Problem

A wire of given material having length *l* and area of cross-section *A* has a resistance of 4 Ω. What would be the resistance of another wire of the same material having length *l*/2 and area of cross-section 2A?

Solution

- Resistance *R* of the wire = 26 Ω
- Diameter *d* = 0.3 mm = 3×10^{-4} m
- Length *l* of the wire = 1 m.
- Resistivity of the metallic wire,

  $\rho = (RA/l) = (R\pi d^2/4l) = \underline{1.84 \times 10^{-6}\ \Omega\ m.}$
- This is the resistivity of manganese.

Solution

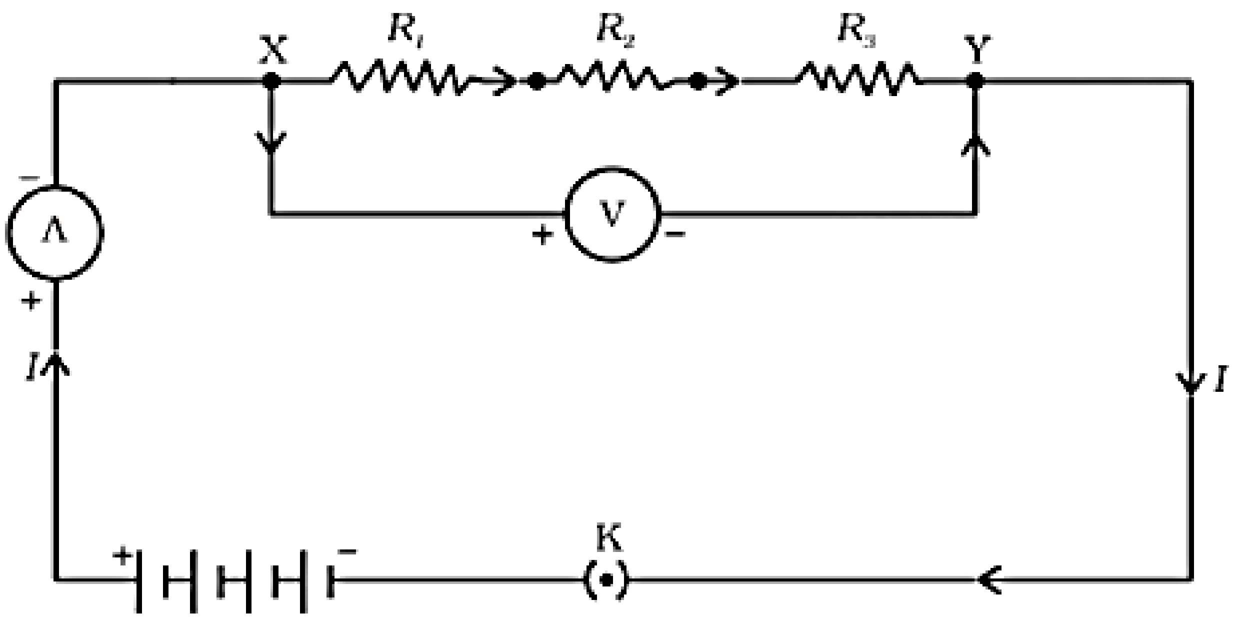
For first wire: $R_1 = \rho\, l/A = 4\ \Omega$

For second wire: $R_2 = \rho \dfrac{l/2}{2A} = \frac{1}{4} \rho\, l/A$

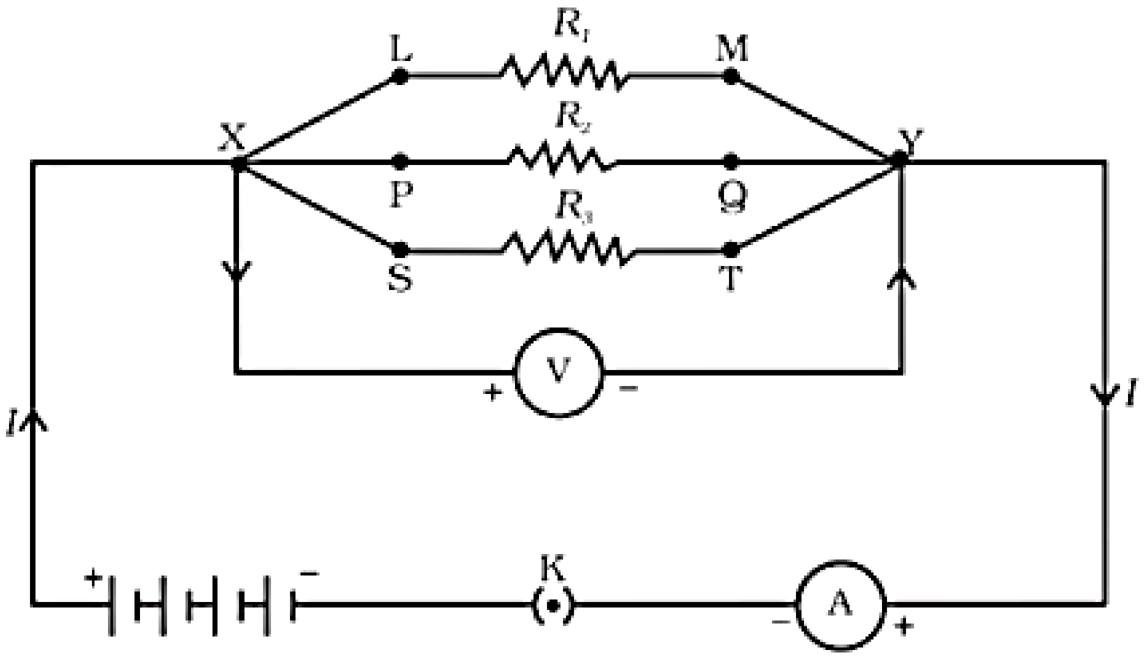
$R_2 = \frac{1}{4} R1 = \underline{1\Omega}$

RESISTANCE OF A SYSTEM OF RESISTORS

- In electrical gadgets, resistors are used in various combinations based on Ohm's law.
- There are 2 methods of joining the resistors: **Resistors in series & Resistors in parallel.**



Resistors in series

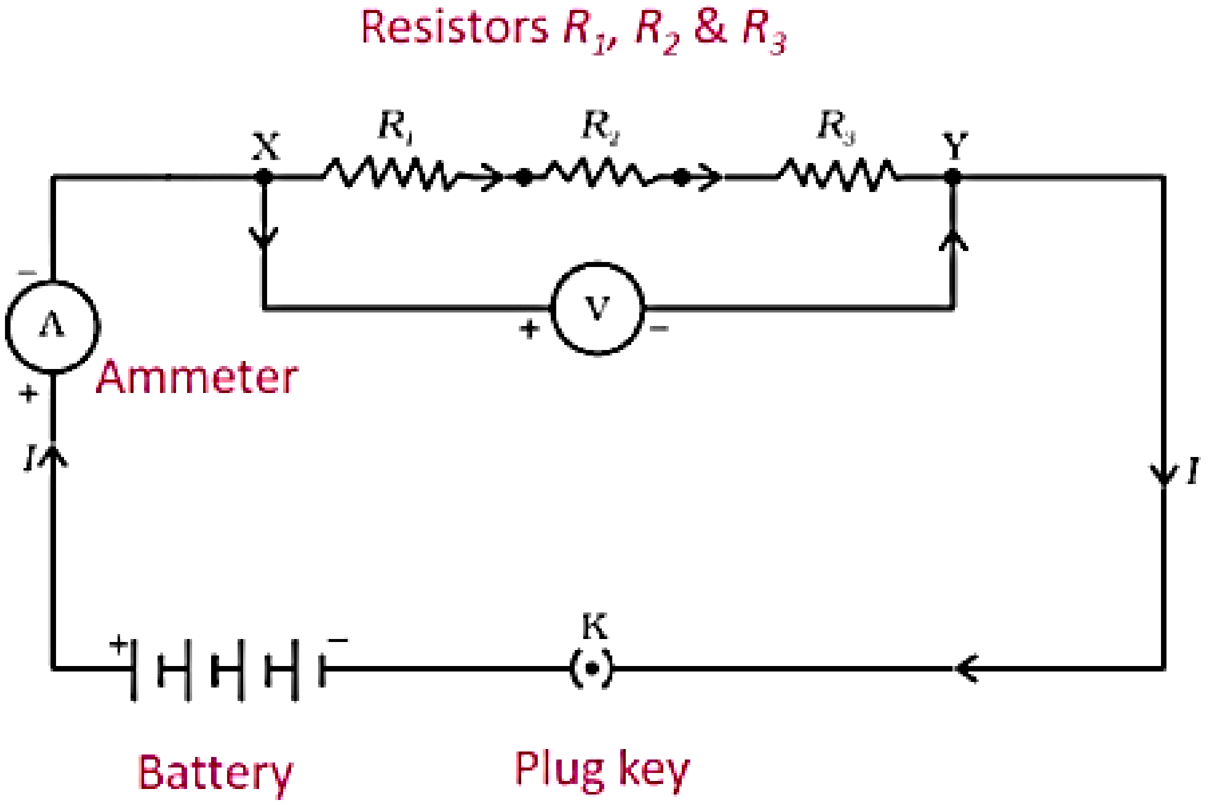


Resistors in parallel

RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Series

- Join three resistors having resistances R_1, R_2 & R_3 (e.g. 1 Ω, 2 Ω, 3 Ω) in series.
- Connect them with a 6 V battery, an **ammeter** and a plug key. Note the ammeter reading.
- Change the position of ammeter in between the resistors. The value is same.
- i.e., in a **series combination** of resistors, the **current is the same** in every part of the circuit or the same current through each resistor.

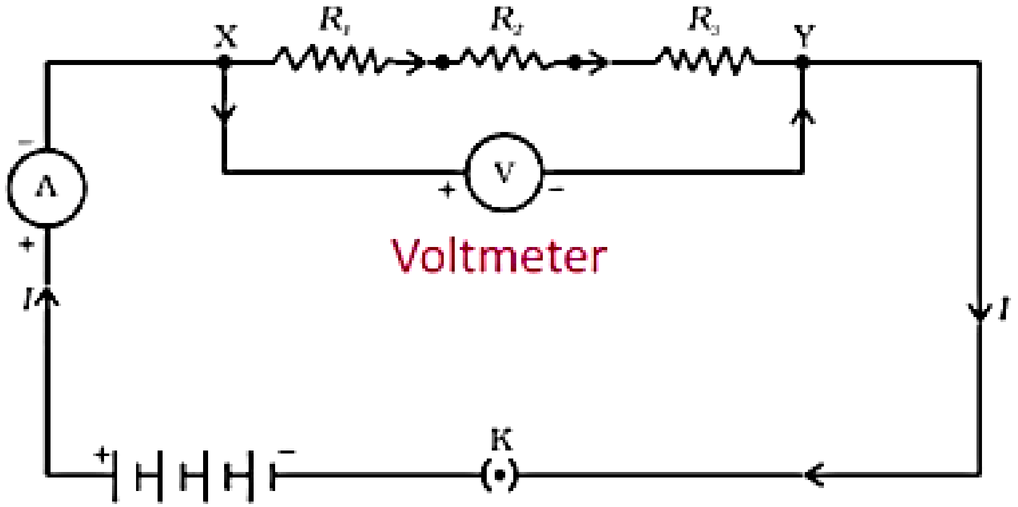


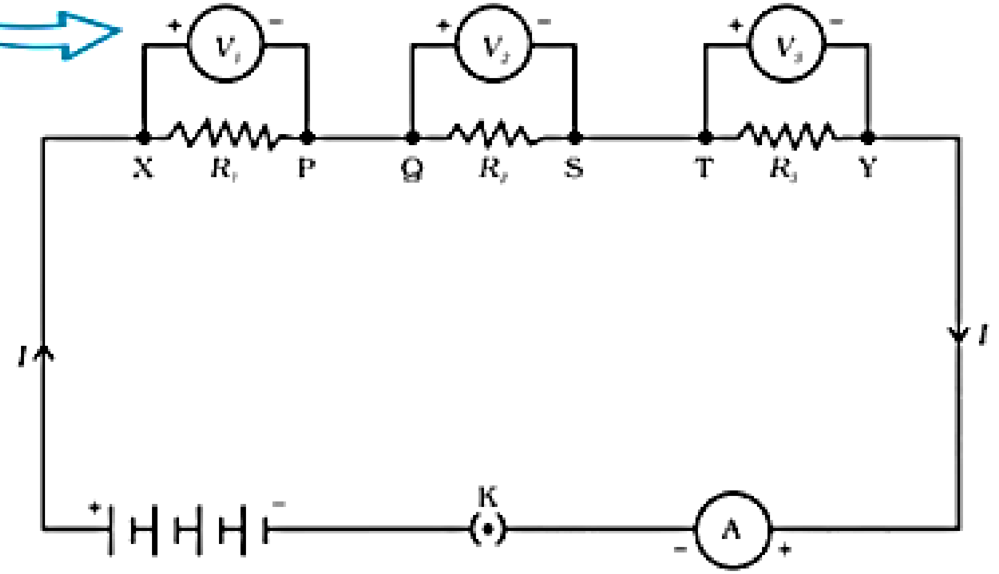
RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Series

- Insert a **voltmeter** across the ends X and Y of the series combination of three resistors. Note the **potential difference (*V*).** Now measure the potential difference across the two terminals of the battery. Compare the two values.
- Now measure the potential differences V_1, V_2 and V_3 across the first, second and third resistors separately.
- The total potential difference V across a combination of resistors in series is equal to the sum of potential differences across the individual resistors.

i.e., $V = V_1 + V_2 + V_3$





RESISTANCE OF A SYSTEM OF RESISTORS

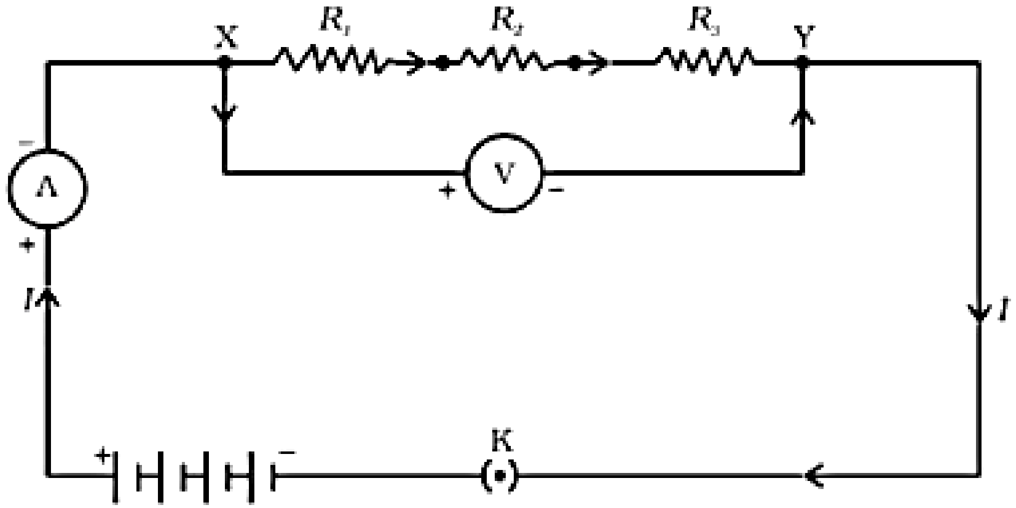
Resistors in Series

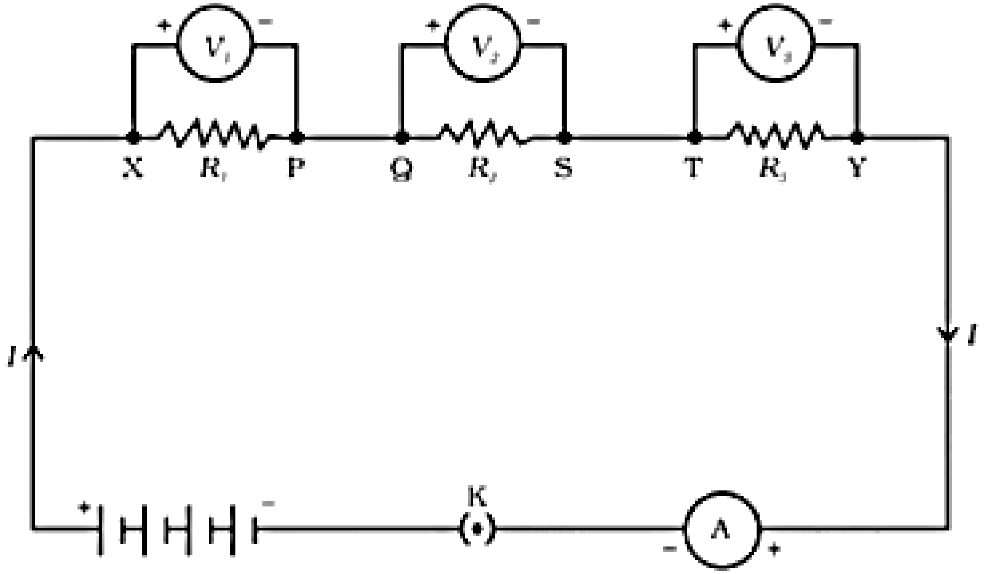
- Let ***I*** be the **current** through this electric circuit. The current through each resistor is also ***I***.
- The three resistors can be replaced by an equivalent single resistor of resistance R, such that the potential difference and the current remains the same.
- Applying the Ohm's law to the entire circuit, $V = I\,R$
- Applying Ohm's law to the three resistors separately,

$V_1 = I\,R_1$ $V_2 = I\,R_2$ $V_3 = I\,R_3$

$I\,R = I\,R_1 + I\,R_2 + I\,R_3$ or $Rs = R_1 + R_2 + R_3$

- When several resistors are joined in series, resistance of the combination *Rs* equals the sum of their individual resistances, R_1, R_2, R_3.



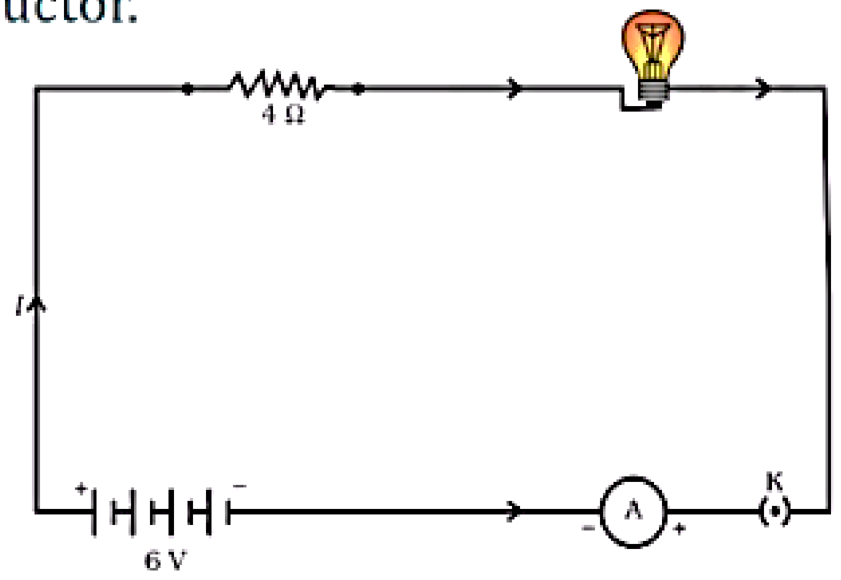


RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Series

Problem

An electric lamp, whose resistance is 20 Ω, and a conductor of 4 Ω resistance are connected to a 6 V battery. Calculate (a) the total resistance of the circuit, (b) the current through the circuit, and (c) the potential difference across the electric lamp and conductor.



Solution

a) Resistance of electric lamp, $R_1 = 20\ \Omega$

Resistance of the conductor, $R_2 = 4\ \Omega$.

∴ Total resistance, $R_s = R_1 + R_2 = 20\ \Omega + 4\ \Omega =$ **<u>24 Ω.</u>**

b) Total potential difference, $V = 6$ V.

Current through the circuit is $I = V/R_s$

$= 6\ V/24\ \Omega$ = **<u>0.25 A.</u>**

c) Potential difference across the electric lamp:

$V_1 = 20\ \Omega \times 0.25\ A$ = **<u>5 V</u>**

Potential difference across the conductor:

$V_2 = 4\ \Omega \times 0.25\ A$ = **<u>1 V</u>**

If the series combination of electric lamp and conductor is replaced by an equivalent resistor, its resistance would be

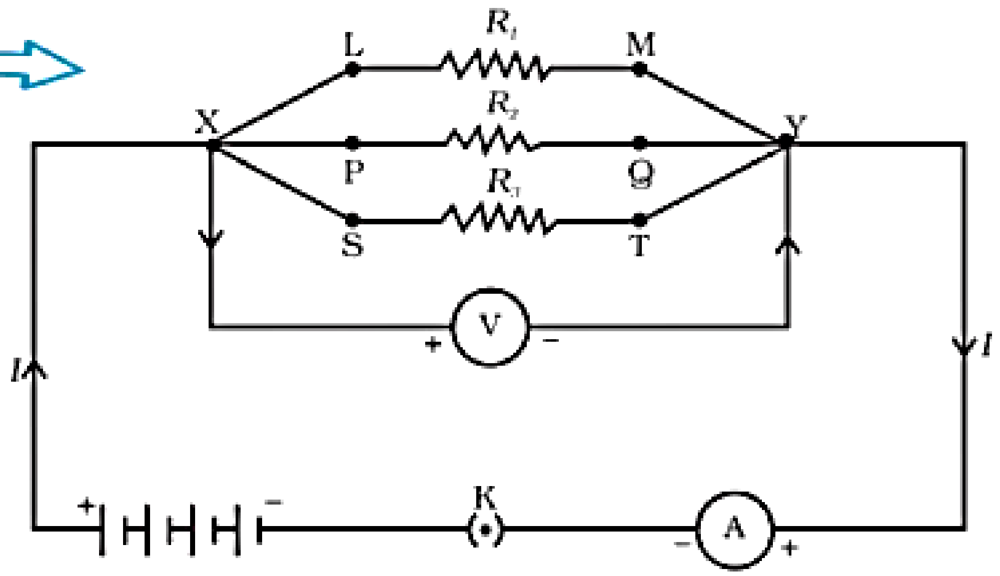
$R = V/I = 6\ V/ 0.25\ A =$ **<u>24 Ω</u>**

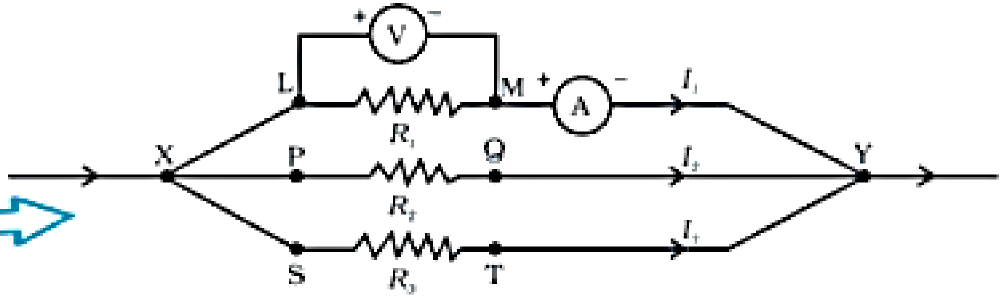
This is equal to the sum of the two resistances.

RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Parallel

- Make a **parallel combination, XY,** of three resistors having resistances R_1, R_2, & R_3 in an electric circuit. Connect a **voltmeter** in parallel with the resistors.
- Note the ammeter reading (I) and the voltmeter reading.
- Voltmeter shows the potential difference V, across the combination. The potential difference across each resistor is also V. This can be checked by connecting the voltmeter across each individual resistor.
- Insert the **ammeter** in series with the resistor R_1. Note the ammeter reading, I_1. Similarly, measure the currents I_2 & I_3 through R_2 & R_3 respectively.





RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Parallel

- The total current *I*, is equal to the sum of the separate currents through each branch.

$$I = I_1 + I_2 + I_3$$

- Let R_p be the equivalent resistance of the parallel combination of resistors.

Hence, $I = V/R_p$

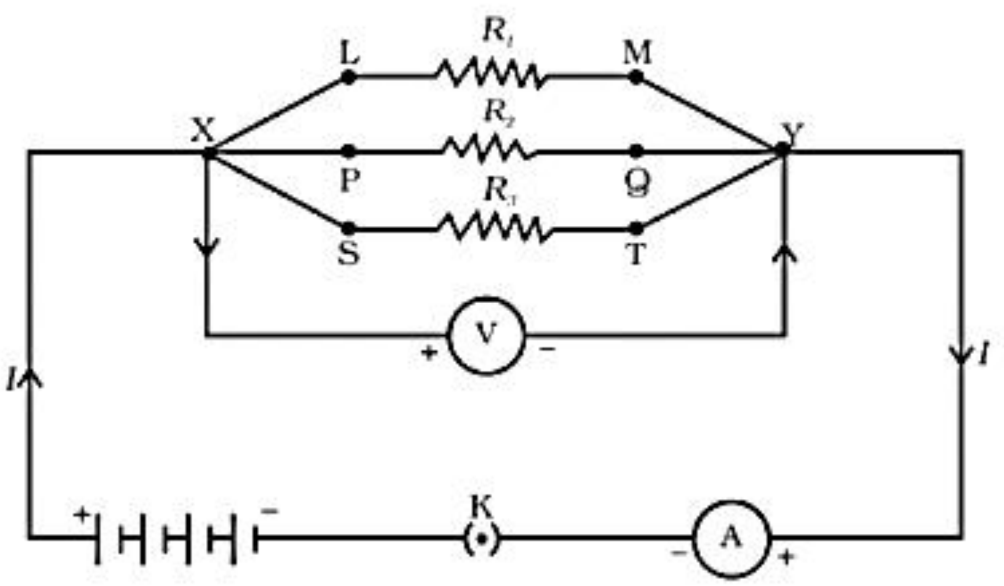
- Applying Ohm's law to each resistor,

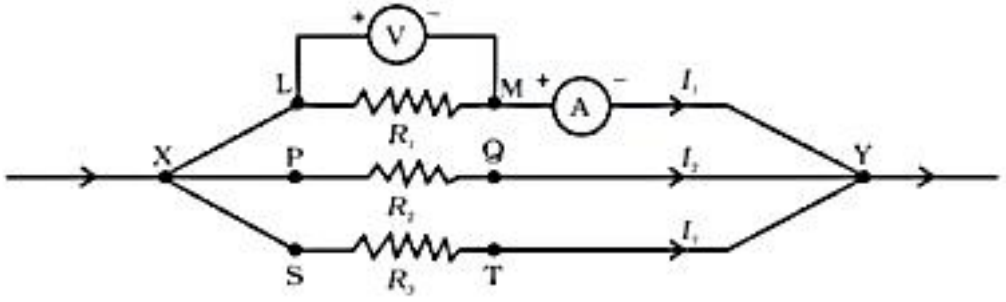
$$I_1 = V/R_1 \qquad I_2 = V/R_2 \qquad I_3 = V/R_3$$

$$V/R_p = V/R_1 + V/R_2 + V/R_3 \quad \text{or}$$

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$$

- Thus, the reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.





RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Parallel

Problem

In the circuit diagram given, suppose the resistors R_1, R_2 & R_3 have the values 5 Ω, 10 Ω, 30 Ω, respectively, which have been connected to a battery of 12 V.

Calculate (a) the current through each resistor, (b) total current in the circuit, and (c) total circuit resistance.

Solution

$R_1 = 5\ \Omega$, $R_2 = 10\ \Omega$, and $R_3 = 30\ \Omega$.

Potential difference across the battery, $V = 12$ V.

This is also the potential difference across each of the individual resistor.

a) The current I_1, through $R_1 = V/R_1 = 12\ \text{V}/5\ \Omega =$ **<u>2.4 A</u>**

The current I_2, through $R_2 = V/R_2 = 12\ \text{V}/10\ \Omega =$ **<u>1.2 A</u>**

The current I_3, through $R_3 = V/R_3 = 12\ \text{V}/30\ \Omega =$ **<u>0.4 A</u>**

b) The total current in the circuit, $I = I_1 + I_2 + I_3$

$= (2.4 + 1.2 + 0.4)$ A = **<u>4 A</u>**

c) The total resistance R_p, is $1/R_p = 1/R_1 + 1/R_2 + 1/R_3$

$1/R_p = 1/5 + 1/10 + 1/30 = 1/3$

Thus, $R_p =$ **<u>3 Ω.</u>**

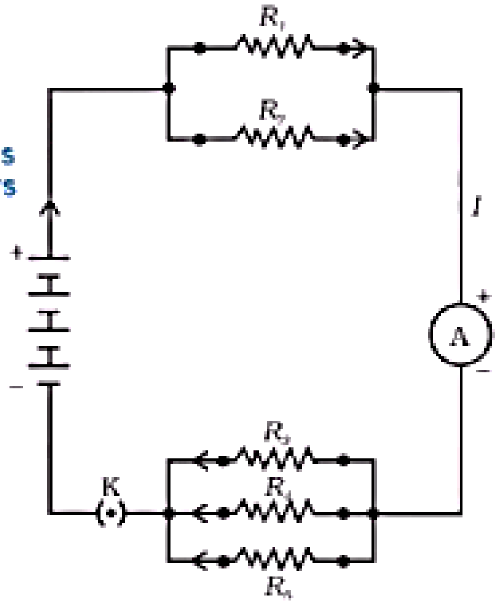
RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Parallel

Problem

If in Fig. given below, R_1 = 10 Ω, R_2 = 40 Ω, R_3 = 30 Ω, R_4 = 20 Ω, R_5 = 60 Ω, and a 12 V battery is connected to the arrangement. Calculate (a) the total resistance in the circuit, and (b) the total current flowing in the circuit.

An electric circuit showing the combination of series and parallel resistors



Solution

Suppose we replace the parallel resistors R_1 and R_2 by an equivalent resistor of resistance, R'. Similarly, we replace the parallel resistors R_3, R_4 and R_5 by an equivalent single resistor of resistance R''.

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$$

∴ $1/R' = 1/10 + 1/40 = 5/40$. i.e., R' = **8 Ω**

$1/R'' = 1/30 + 1/20 + 1/60 = 6/60$. i.e., R'' = **10 Ω**

Thus, the total resistance, R = R′ + R″ = **18 Ω**

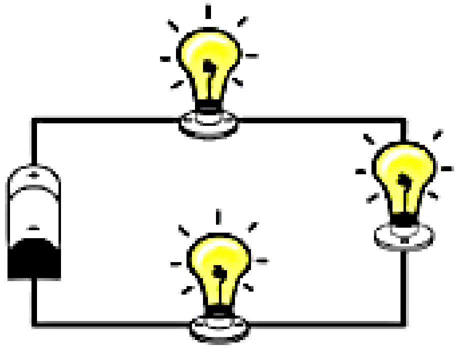
The current in circuit, $I = V/R$ = 12 V/18 Ω = **0.67 A**

RESISTANCE OF A SYSTEM OF RESISTORS

Resistors in Parallel

Disadvantages of Series Circuit

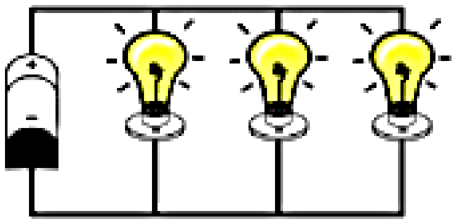
- The current is constant throughout the electric circuit. So, it is impracticable to connect an electric bulb and an electric heater in series, because they need currents of different values.
- When one component fails, the circuit is broken and none of the components works. E.g. it is very difficult to locate the dead bulb in fairy lights.



Series Circuit

Advantages of Parallel Circuit

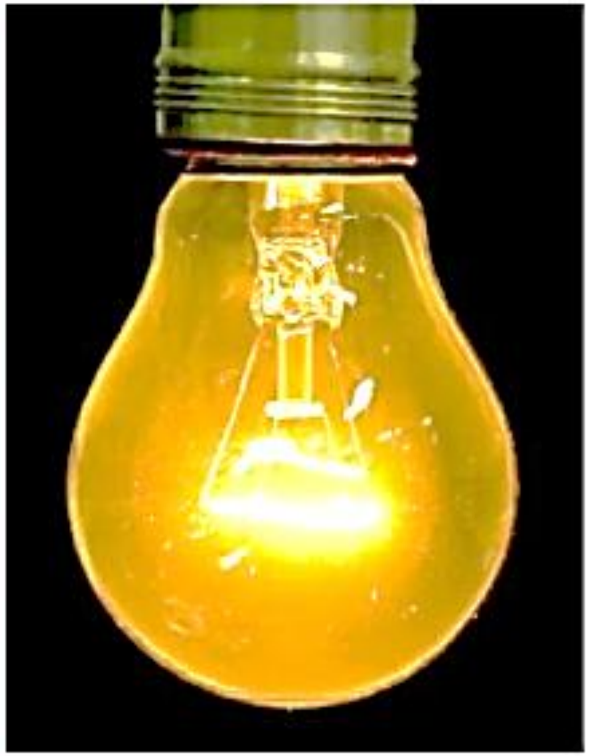
- It divides the current through the electrical gadgets.
- The total resistance is decreased. This is helpful when each gadget has different resistance and requires different current to operate properly.



Parallel Circuit

HEATING EFFECT OF ELECTRIC CURRENT

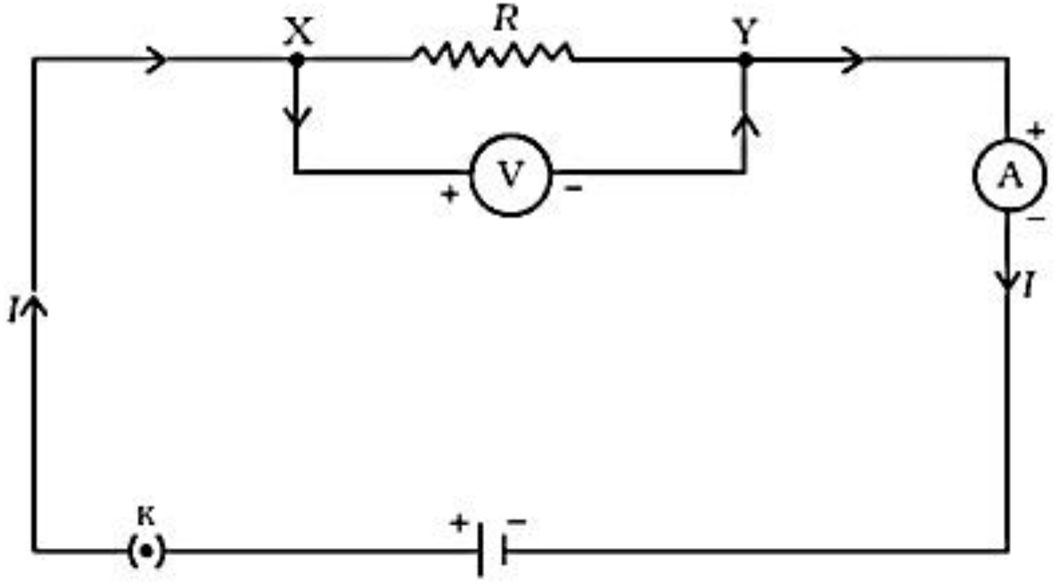
- A battery or a cell is a source of electrical energy. It generates potential difference that sets the electrons in motion to flow the current through a resistor or a system of resistors.
- A part of the source energy may be consumed into useful work (e.g. rotation of an electric fan). Rest of the energy is lost as **heat.** E.g., an electric fan becomes warm if used for longer time.

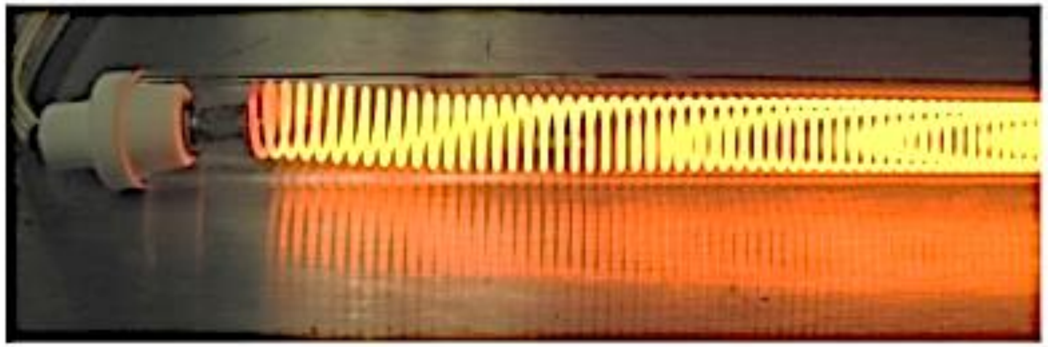
HEATING EFFECT OF ELECTRIC CURRENT

- If an electric circuit is purely resistive (i.e. a configuration of resistors only connected to a battery), the source energy is dissipated entirely as heat. This is called **heating effect of electric current.**
- Consider a **current *I*** flowing through a resistor of **resistance *R*.** Let the **potential difference** across it be ***V*** and ***t*** is the **time** during which a **charge *Q*** flows across.
- The work done in moving the charge *Q* through a potential difference *V* is ***VQ*.** Therefore, the source must supply energy equal to *VQ* in time *t*. Hence the **power** input to the circuit by the source is

$$P = V\frac{Q}{t} = VI$$



A steady current in a purely resistive electric circuit.

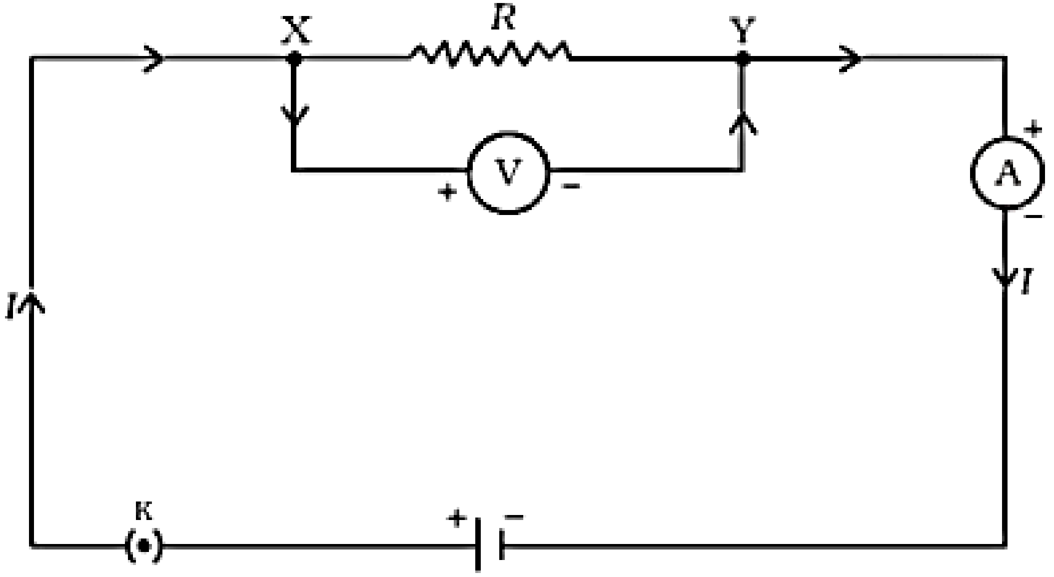


HEATING EFFECT OF ELECTRIC CURRENT

- Or the energy supplied to the circuit by the source in time *t* is ***P* × *t*, i.e., *VIt*.** This energy is dissipated in the resistor as **heat (H).**

  Therefore, $H = VIt$

- Applying Ohm's law ($V = IR$), $H = I^2Rt$.
- This is called **Joule's law of heating.** It implies that heat produced in a resistor is directly proportional to
  - The **square of current** for a given resistance.
  - **Resistance** for a given current.
  - The **time** for which current flows through resistor.
- In practical situations, when an electric appliance is connected to a voltage source, Eq. $H = I^2Rt$ is used after calculating the current using the relation $I = V/R$.



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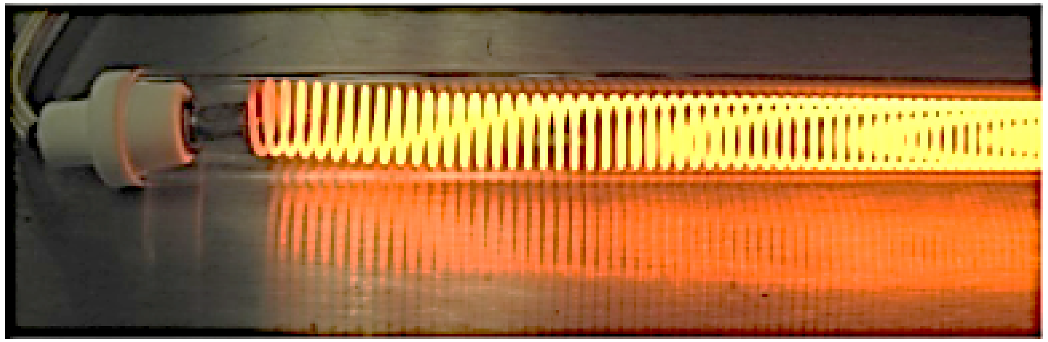


HEATING EFFECT OF ELECTRIC CURRENT

Problem

An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum. The voltage is 220 V.

What are the current and the resistance in each case?

Solution

Power input, $P = VI$

Thus the current $I = P/V$

a) **When heating is at the maximum rate:**

$I = 840\ \text{W}/220\ \text{V}$ = **3.82 A**

Resistance of the electric iron is

$R = V/I = 220\ \text{V}/3.82\ \text{A}$ = **57.60 Ω**

b) **When heating is at the minimum rate:**

$I = 360\ \text{W}/220\ \text{V}$ = **1.64 A**

Resistance of the electric iron is

$R = V/I = 220\ \text{V}/1.64\ \text{A}$ = **134.15 Ω.**

HEATING EFFECT OF ELECTRIC CURRENT

Problem

100 J of heat is produced each second in a 4 Ω resistance. Find the potential difference across resistor.

Solution

$H = 100$ J, $R = 4\ \Omega$, $t = 1$ s, $V = ?$

$$H = I^2Rt$$

So, the current through the resistor is

$I = \sqrt{(H/Rt)}$

$= \sqrt{[100\ \text{J}/(4\ \Omega \times 1\ \text{s})]}$ $=$ **5 A**

Thus the potential difference across the resistor is

$V = IR$ $= 5\ \text{A} \times 4\ \Omega$ $=$ **20 V**

HEATING EFFECT OF ELECTRIC CURRENT

Practical Applications of Heating Effect of Electric Current

Due to heating effect, electrical energy is lost as heat. Also, it alters the properties of components in electric circuits. But **heating effect (Joule's heating)** has many applications:

a. To make devices such as **electric laundry iron, electric toaster, electric oven, electric kettle & electric heater.**

Electric iron

Electric toaster

Electric heater

Electric oven

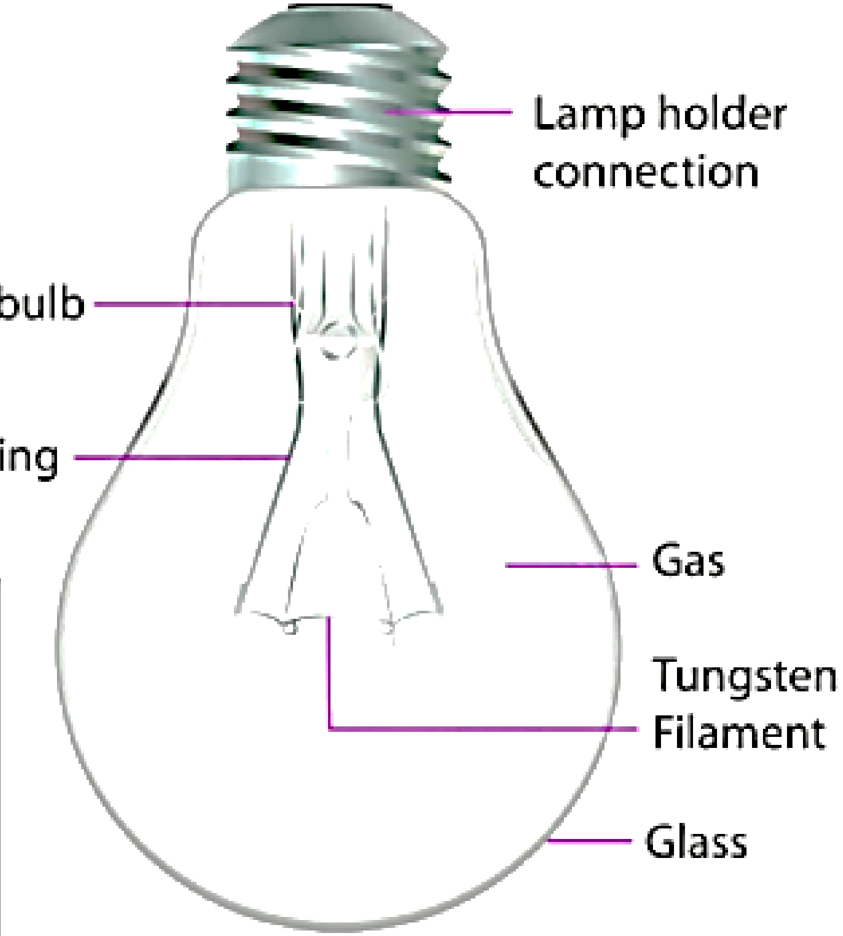
Electric kettle

HEATING EFFECT OF ELECTRIC CURRENT

Practical Applications of Heating Effect of Electric Current

b. To produce **light in electric bulb.** Here, the **filament** made of metals with high melting point can retain much heat. So it gets very hot and emits light.

E.g. **tungsten** (melting point 3380°C) is used to make filaments. Filament should be thermally isolated, using insulating support. The bulbs are filled with chemically inactive **nitrogen** and **argon** gases to prolong the life of filament. Most of the power consumed by the filament appears as heat, but a small part is radiated as light.



HEATING EFFECT OF ELECTRIC CURRENT

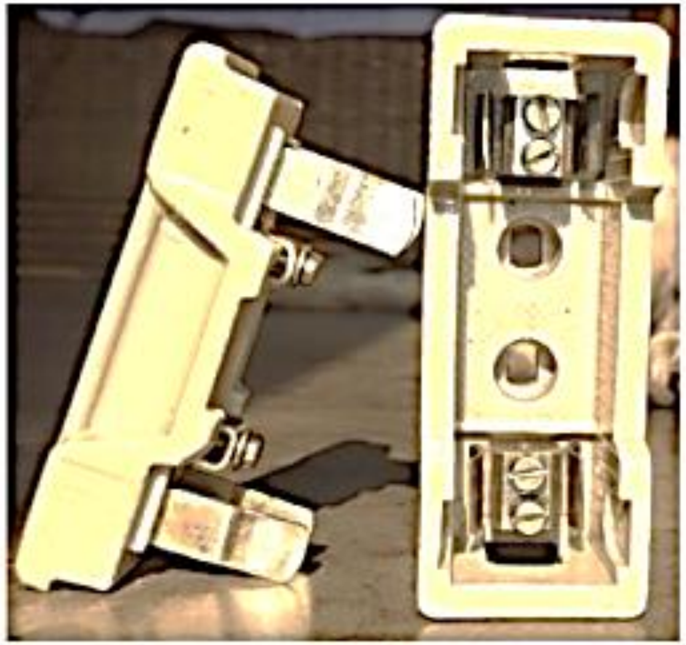
Practical Applications of Heating Effect of Electric Current

c. To make **fuse** used **in electric circuits.**

It protects circuits and appliances by **stopping the overflow of electric current.** The fuse is placed in series with the device. It consists of a **piece of wire** made of a metal or an alloy of suitable melting point (aluminium, copper, iron, lead etc.). During the overflow of the current, temperature of the fuse wire increases. It melts the fuse wire and breaks the circuit.

The fuse wire is encased in a **cartridge of porcelain** or similar material with metal ends.

The fuses used for domestic purposes are rated as **1A, 2A, 3A, 5A, 10A,** etc. E.g. when an electric iron which consumes 1 kW electric power is operated at 220 V, 4.54 A current (1000/220) flows in the circuit. In this case, a 5 A fuse must be used.



ELECTRIC POWER

- **Power** is the rate of doing work or rate of consumption of energy.
- Equation $H = I^2Rt$ gives the rate at which electric energy is dissipated or consumed in an electric circuit. This is also termed as **electric power.** The **power P** is given by

$$P = VI$$

Or $$P = I^2R = V^2/R$$

- The SI unit of electric power is **watt (W).** It is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1 V.

Thus, 1 W = 1 volt × 1 ampere = 1 V A

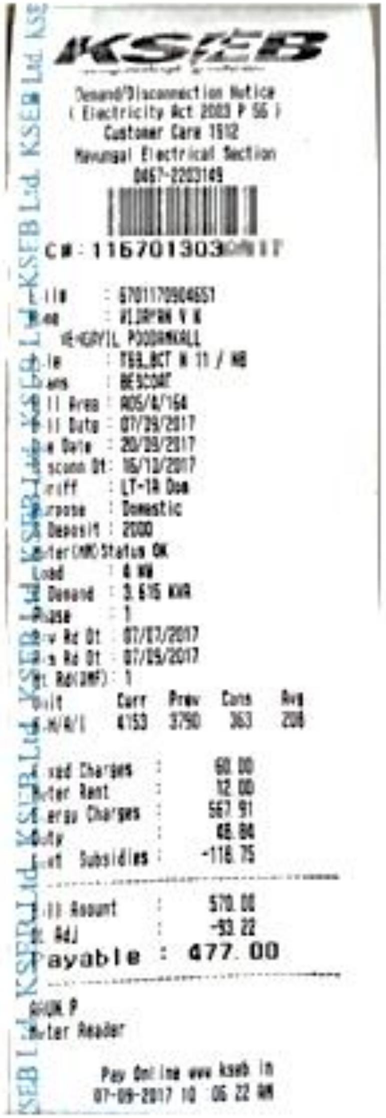
- Watt is a very small unit. So, practically a much larger unit called **kilowatt** (1000 watts) is used.

ELECTRIC POWER

- Electrical energy is the product of power and time. Its unit is **watt hour (W h).**
- One watt hour is the energy consumed when **1 watt of power** is used for **1 hour.**
- The commercial unit of electric energy is **kilowatt hour (kW h),** commonly known as **'unit'.**
- 1 kW h = 1000 watt × 3600 second

  = 3.6×10^6 watt second = **3.6×10^6 joule (J)**
- In an electric circuit, electrons are not consumed. We pay for energy to move electrons through electric gadgets.

Energy meter



ELECTRIC POWER

Problem

An electric bulb is connected to a 220 V generator. The current is 0.50 A. What is the power of the bulb?

Solution

$P = VI$

$= 220\ V \times 0.50\ A$

$= 110\ J/s$

$=$ **110 W**

Problem

An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs 3.00 per kW h?

Solution

Total energy consumed by the refrigerator in 30 days:

$400\ W \times 8.0\ hr/day \times 30\ days$

$= 96000\ W\ h$ $=$ **96 kW h**

∴ cost of energy to operate the refrigerator for 30 days:

$96\ kW\ h \times$ Rs 3.00 per kW h $=$ **Rs 288.00**


thank you