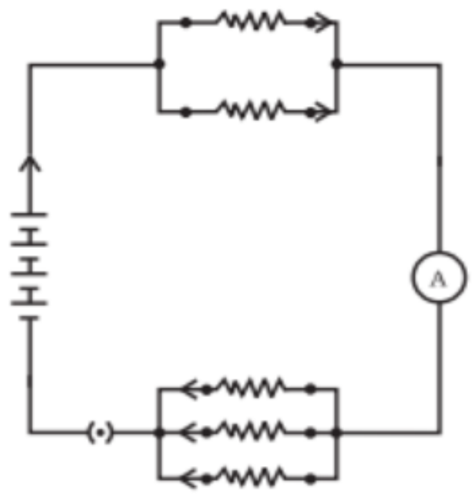
CHAPTER 11

Electricity



1064CH12

Hello mere pyare baccho

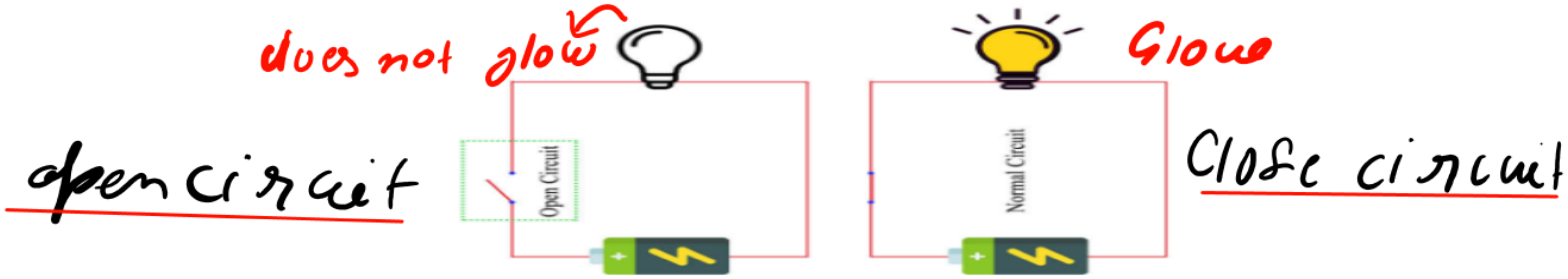
aj hum sabhi Electricity

chapter ko study karenge -

Electricity has an important place in modern society. It is a controllable and convenient form of energy for a variety of uses in homes, schools, hospitals, industries and so on. What constitutes electricity? How does it flow in an electric circuit? What are the factors that control or regulate the current through an electric circuit? In this Chapter, we shall attempt to answer such questions. We shall also discuss the heating effect of electric current and its applications.

11.1 ELECTRIC CURRENT AND CIRCUIT

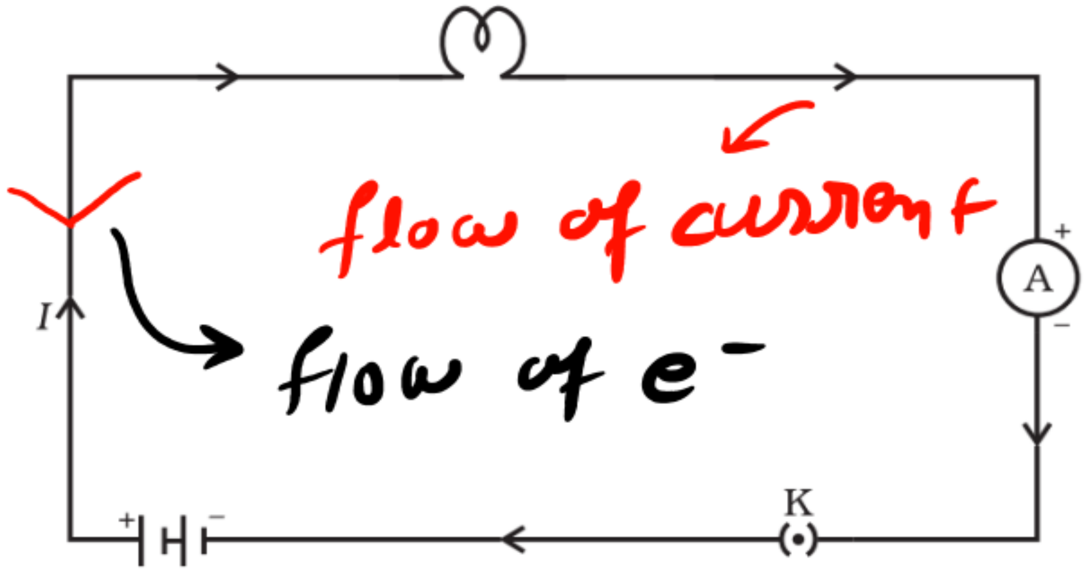
We are familiar with air current and water current. We know that flowing water constitute water current in rivers. Similarly, if the electric charge flows through a conductor (for example, through a metallic wire), we say that there is an electric current in the conductor. In a torch, we know that the cells (or a battery, when placed in proper order) provide flow of charges or an electric current through the torch bulb to glow. We have also seen that the torch gives light only when its switch is *on*. What does a switch do? A switch makes a conducting link between the cell and the bulb. A continuous and closed path of an electric current is called an electric circuit. Now, if the circuit is broken anywhere (or the switch of the torch is turned *off*), the current stops flowing and the bulb does not glow.



current –

How do we express electric current? Electric current is expressed by the amount of charge flowing through a particular area in unit time. In other words, it is the rate of flow of electric charges. In circuits using metallic wires, electrons constitute the flow of charges. However, electrons were not known at the time when the phenomenon of electricity was first observed. So, electric current was considered to be the flow of positive charges and the direction of flow of positive charges was taken to be 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, which are negative charges.

circuit



$$\text{current} = \frac{\text{charge}}{\text{time}}$$

$$I = \frac{Q}{t}$$

[where, Q = no. of charge

$Q = ne$

t = time taken

or

$$Q = It$$

$\therefore Q = ne$

$$\therefore I = \frac{ne}{t}$$

- unit of current → A
- device → Ammeter
- Unit of charge (C) → coulomb

A coulomb (C) is the standard unit of electric charge in the International System of Units (SI).

- $1e = 1.6 \times 10^{-19}$ C
- $1C = 6.25 \times 10^{18}$ e

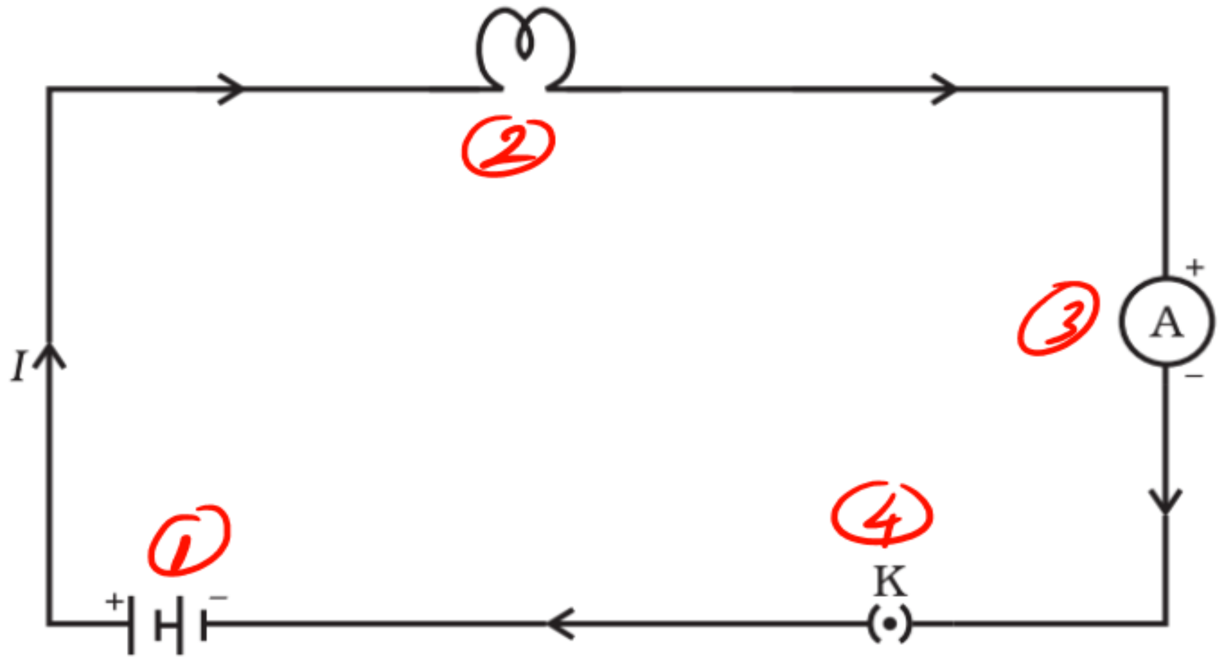
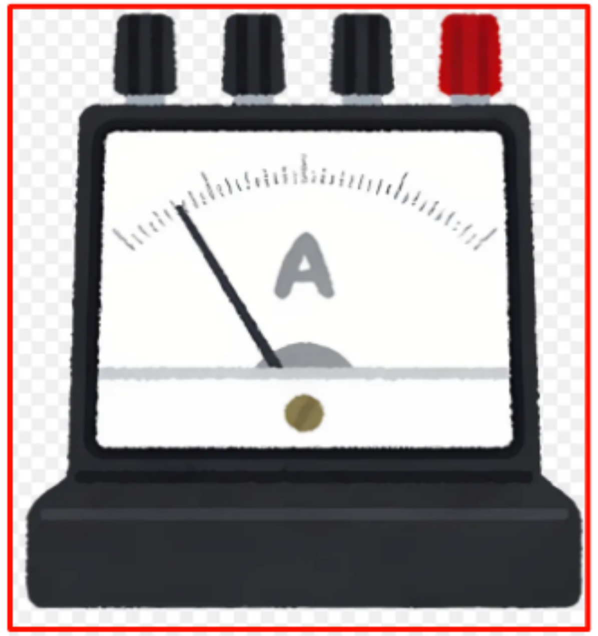


Figure 11.1
A schematic diagram of an electric circuit comprising – cell, electric bulb, ammeter and plug key

An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit through which the current is to be measured. Figure 11.1 shows the schematic diagram of a typical electric circuit comprising a cell, an electric bulb, an ammeter and a plug key. Note that the electric current flows in the circuit from the positive terminal of the cell to the negative terminal of the cell through the bulb and ammeter.



→ It is a device which is used to measure current in the circuit. → Ammeter (A)

$1\,mA = 10^{-3}\,A$

$1\,\mu A = 10^{-6}\,A$

→ Ammeter is always connected in series.

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.

$I = 0.5 A$

$t = 10$ min

$t = 10 \times 60$ sec

$t = 600$ sec

$Q = ?$

$Q = I \times t$

$Q = 0.5 \times 600$

$Q = 5 \times 60$

$= 300 C$ Ans

QUESTIONS

1. What does an electric circuit mean?
2. Define the unit of current.
3. Calculate the number of electrons constituting one coulomb of charge.

① → Close circuit

- **Power source**: A battery or generator that supplies energy to the circuit
- **Load**: A device that uses electricity, like a light bulb, heater, or computer
- **Conductor**: A material that carries the current, like copper wire
- **Switch**: A device that can open or close the circuit to control the flow of electricity

② → unit of current → Ampere (A)

③ → $1C = 6.25 \times 10^{18}$ electrons

ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

We define the electric potential difference between two points in an electric circuit carrying some current as the work done to move a unit charge from one point to the other –

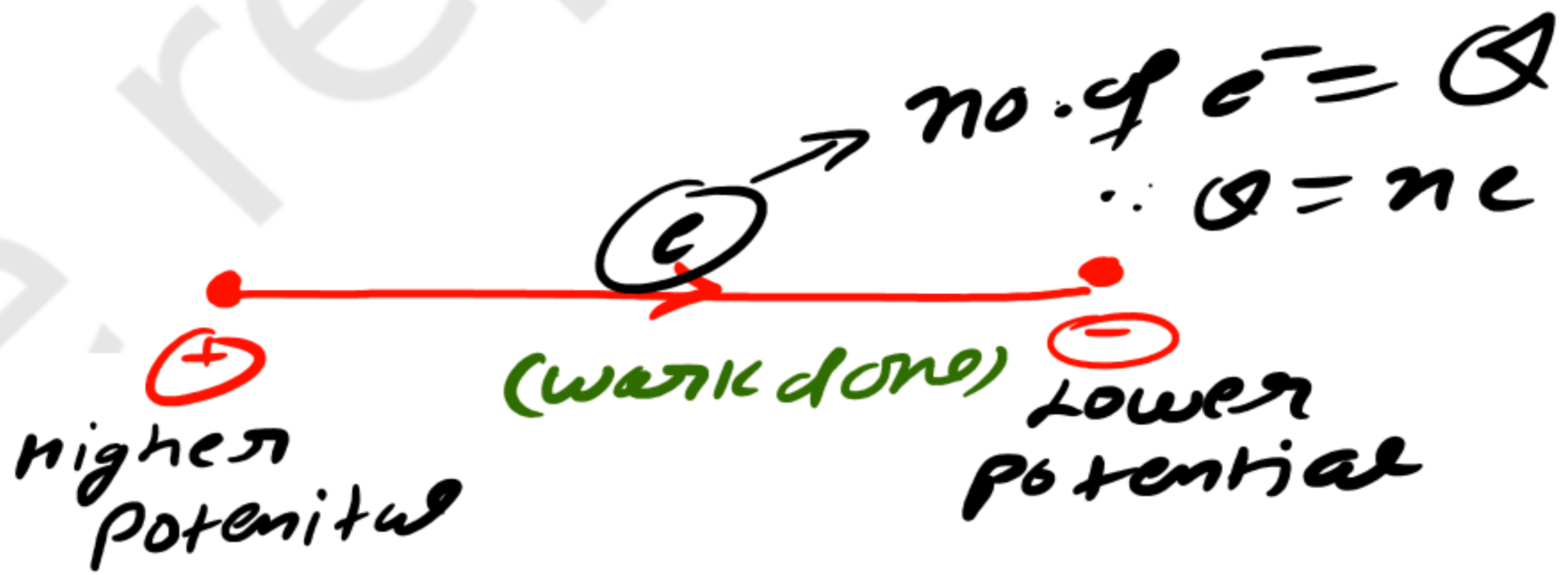
Potential difference (V) between two points = Work done (W)/Charge (Q)

$$V = W/Q \quad (11.2)$$

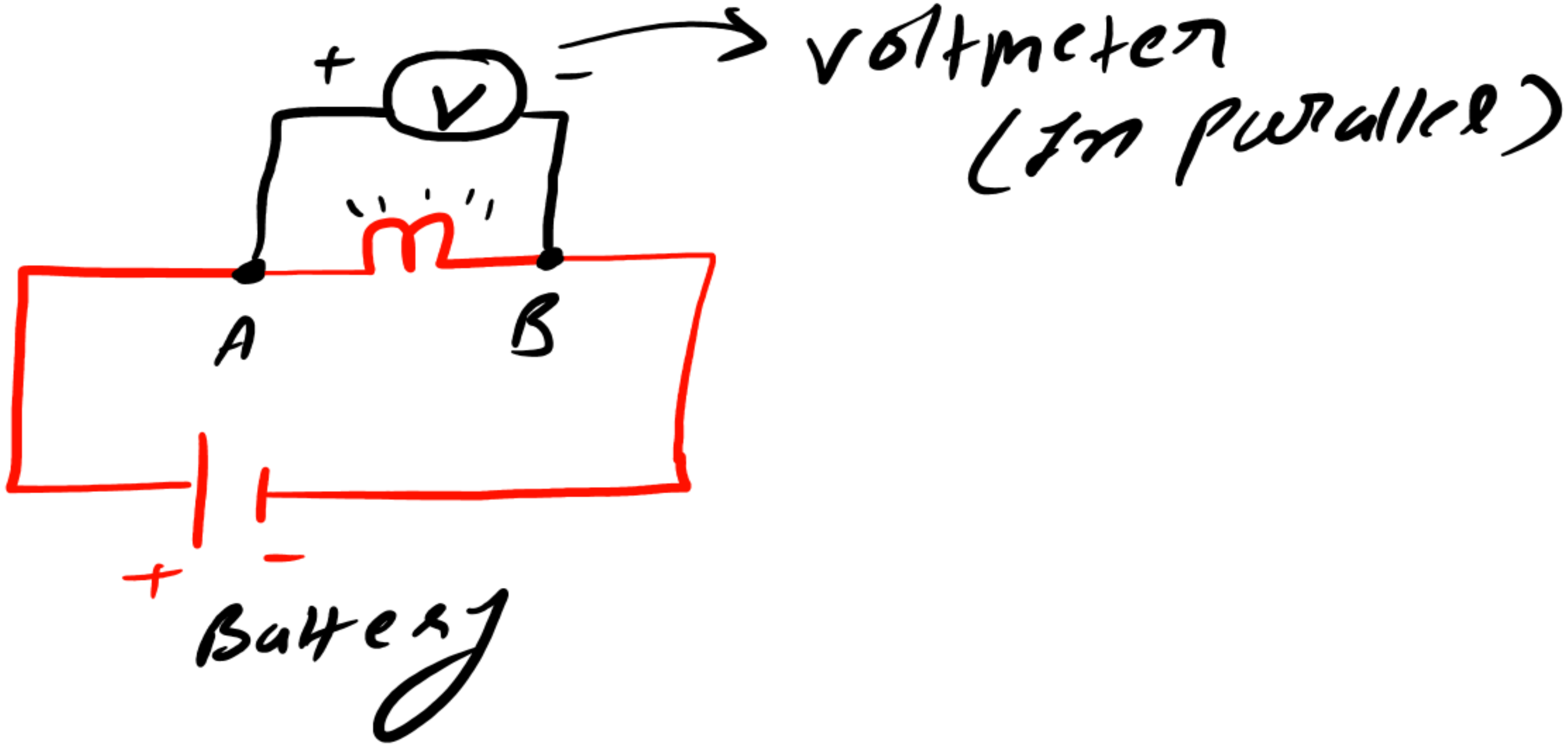
The SI unit of electric potential difference is volt (V), named after Alessandro Volta (1745–1827), an Italian physicist. One volt is the potential difference between two points in a current carrying conductor when 1 joule of work is done to move a charge of 1 coulomb from one point to the other.

Therefore, $1 \text{ volt} = \dfrac{1 \text{ joule}}{1 \text{ coulomb}}$

[volt = J/C]



The potential difference is measured by means of an instrument called the voltmeter. The voltmeter is always connected in parallel across the points between which the potential difference is to be measured.



Difference Between Voltage and Current

Voltage	Current
Voltage is the potential difference between two points in an electric field.	Current is the rate of flow of charges between two points caused by voltage.
Symbol of voltage is “ V “	Symbol of current is “ I “.
SI Unit of voltage is volt.	SI Unit of current is Ampere.
Its formula is V= W/q	Its formula is I = Q/t
Voltage remains same in Parallel combination.	Current remain s same in series circuit.

Example 11.2

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

Sol

$W = ?$

$Q = 2C$

Pd $(V) = 12V$

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

$12 = \frac{W}{2}$

$W = 24J$

Q U E S T I O N S

1. Name a device that helps to maintain a potential difference across a conductor.
2. What is meant by saying that the potential difference between two points is 1 V?
3. How much energy is given to each coulomb of charge passing through a 6 V battery?

Sol-

(1) → voltmeter

(2) → $1V = \frac{1J}{1C}$

(3) → Energy (W) = ?

$Q = 1C$

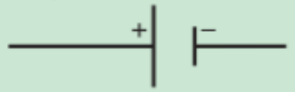
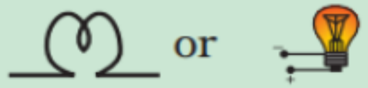
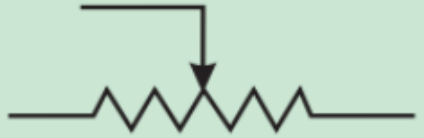
P.d (V) = 6V

$W = V \times Q$

$W = 1 \times 6$

$W = 6J$

CIRCUIT DIAGRAM

Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	 (more than 2 cells)
3	Plug key or switch (open)	 does not flow current
4	Plug key or switch (closed)	 flow (current)
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	
8	A resistor of resistance (R)	
9	Variable resistance or rheostat	 or 
10	Ammeter (A)	
11	Voltmeter (V)	

Galvanometer

OHM'S LAW

In 1827, a German physicist Georg Simon Ohm (1787–1854) found out the relationship between the current *I*, flowing in a metallic wire and the potential difference across its terminals. The potential difference, *V*, across the ends of a given metallic wire in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same. This is called Ohm's law. In

V is directly prop to current (I)

$V \propto I$

$V = RI$

↳ Resistance constant

Temp is also constant

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 through it. Its SI unit is ohm, represented by the Greek letter Ω. According to Ohm's law,

SI unit of (R) is ohm (Ω)

$R = \frac{V}{I}$ → $R \propto V$

$R \propto \frac{1}{I}$ [It means that (R) is resist the flow of (I)]

Extra Gyan —

It is obvious from Eq. (11.7) that the current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved. In many practical cases it is necessary to increase or decrease the current in an electric circuit. A component used to regulate current without changing the voltage source is called variable resistance. In an electric circuit, a device called rheostat is often used to change the resistance in the circuit. We will now study about electrical resistance of a conductor with the help of following Activity.

2R → $\frac{1}{2}$ → current is half of R

(double) (half)

Current → control → Resistance

Resistance → control → variable Resistance

FACTORS ON WHICH THE RESISTANCE OF A CONDUCTOR DEPENDS

resistance of the conductor depends (i) on its length, (ii) on its area of cross-section, and (iii) on the nature of its material. Precise measurements have shown that resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A). That is,

R is directly prop. to length (l)

$R \propto l$ — (i)

R is inversely prop. to Area (A)

$R \propto \frac{1}{A}$ — (ii)

from (i) and (ii) equation —

$R \propto l \times \frac{1}{A}$

$R \propto \frac{l}{A}$

$R = \rho \frac{l}{A}$

↳ Resistivity of material (Rho)

Unit of ρ —

$R = \rho \frac{l}{A}$

$RA = \rho l$

$\frac{RA}{l} = \rho$

$\rho = \frac{\Omega \times m \times m}{m}$

$\rho = \Omega\text{-}m$

ohm-meter

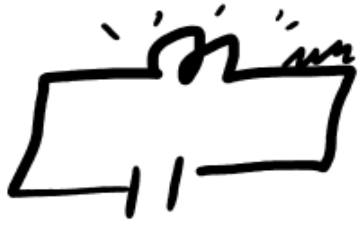
	Material	Resistivity (Ω m)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and 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}

* *You need not memorise these values. You can use these values for solving numerical problems.*

Yaad karne ki
Jarurat nahi hai
question me isko
value given rahega.

(a) How much current will an electric bulb draw from a 220 V source, if the resistance of the bulb filament is 1200 Ω? (b) How much current will an electric heater coil draw from a 220 V source, if the resistance of the heater coil is 100 Ω?

Sol -



(a)

$V = 220V$

$R = 1200Ω$

$I = ?$

$V = IR$

$220 = 1200 \times I$

$I = \frac{22}{120} = \frac{11}{60}$

$I = \frac{11}{60} = 0.18 A$

(b)

$I = ?$

$V = 220V$

$R = 100Ω$

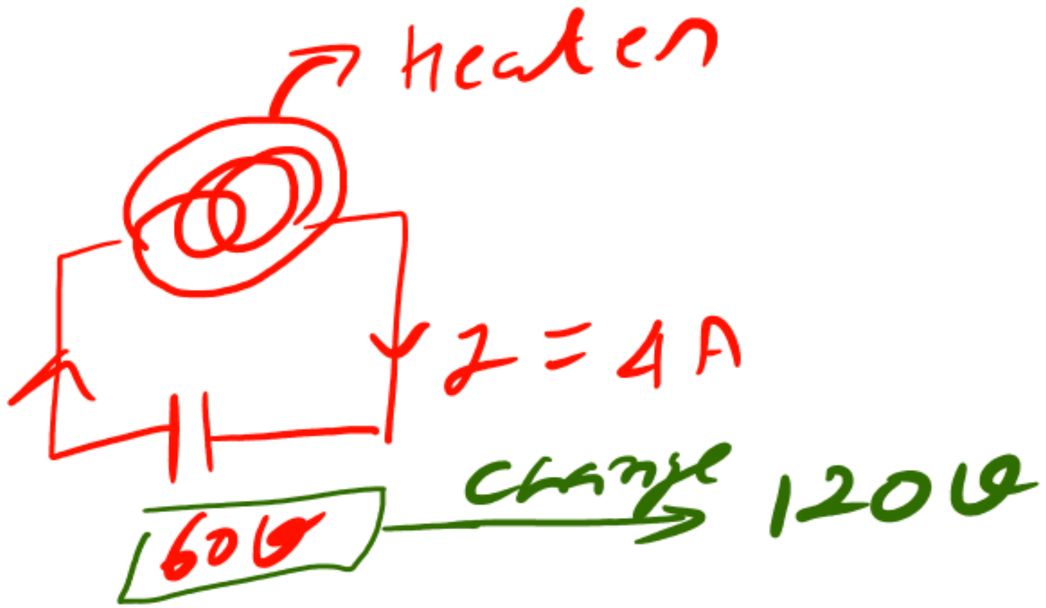
$I = \frac{V}{R} = \frac{220}{100} = \frac{22}{10} = \frac{11}{5}$

$I = 2.2A$

Example 11.4

The 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?

Solⁿ



$\because V = IR$

$60 = 4 \times R$

$R = 15\,\Omega$

$I = ?$

$R = 15\,\Omega$

$V = 120$

$\because V = IR$

$120 = I \times 15$

$I = 8\,A$

Example 11.5

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? Using Table 11.2, predict the material of the wire.

$A = \pi r^2$

$l = 1\,m$

$R = 26\,\Omega$

$D = 0.3\,mm$

$r = \left(\frac{0.3}{2} \times 10^{-3}\,m\right)$

$\rho = ?$

$\because R = \frac{\rho l}{A}$, $A \to \pi r^2$

mm → 10^{-3} m

$26 = \frac{\rho \times 1}{3.14 \times \left(\frac{0.3}{2} \times 10^{-3}\right)^2}$

$26 \times 3.14 \times \frac{0.09 \times 10^{-6}}{4} = \rho$

$13 \times 1.57 \times 0.09 \times 10^{-6} = \rho$

$\rho = 1.83 \times 10^{-6}$

Example 11.6

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 $2A$?

$\rho = \frac{4A}{l}$ — (1)

$\rho = R' \times 2A \div \frac{l}{2}$ — (2)

$\rho = \frac{R' 2A\, 2}{l}$

$\rho = \frac{4R'A}{l}$

$\frac{4A}{l} = \frac{4R'A}{l}$

$4 = 4R'$

$R' = 1\Omega$

∴ $R = \frac{\rho l}{A}$

$RA = \rho l$

$\rho = \frac{RA}{l}$

QUESTIONS

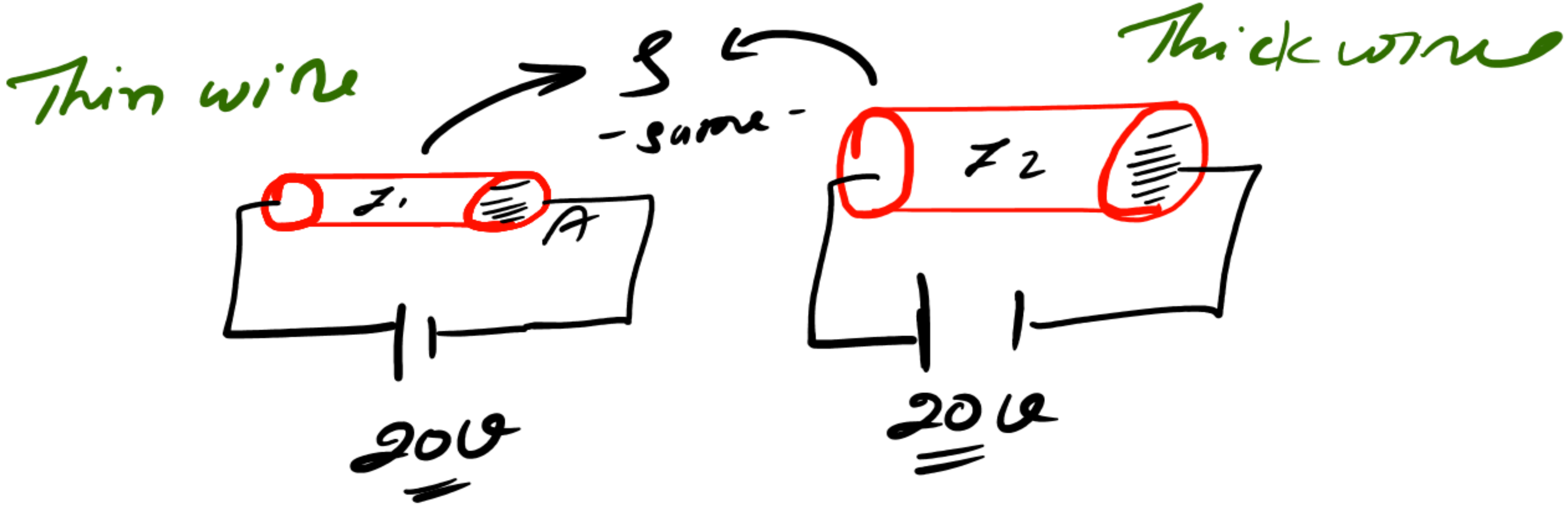
1. On what factors does the resistance of a conductor depend?
2. Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source? Why?
3. Let the resistance of an electrical component remains constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?
4. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal?
5. Use the data in Table 11.2 to answer the following –
   (a) Which among iron and mercury is a better conductor?
   (b) Which material is the best conductor?

(1) (a) → on the length of the wire

(b) → cross section of area

(c) → nature of materials

(2) thin wire because –



$$I_2 > I_1$$

I_2 is more than I_1 due to

I is directly pro. to the (A)

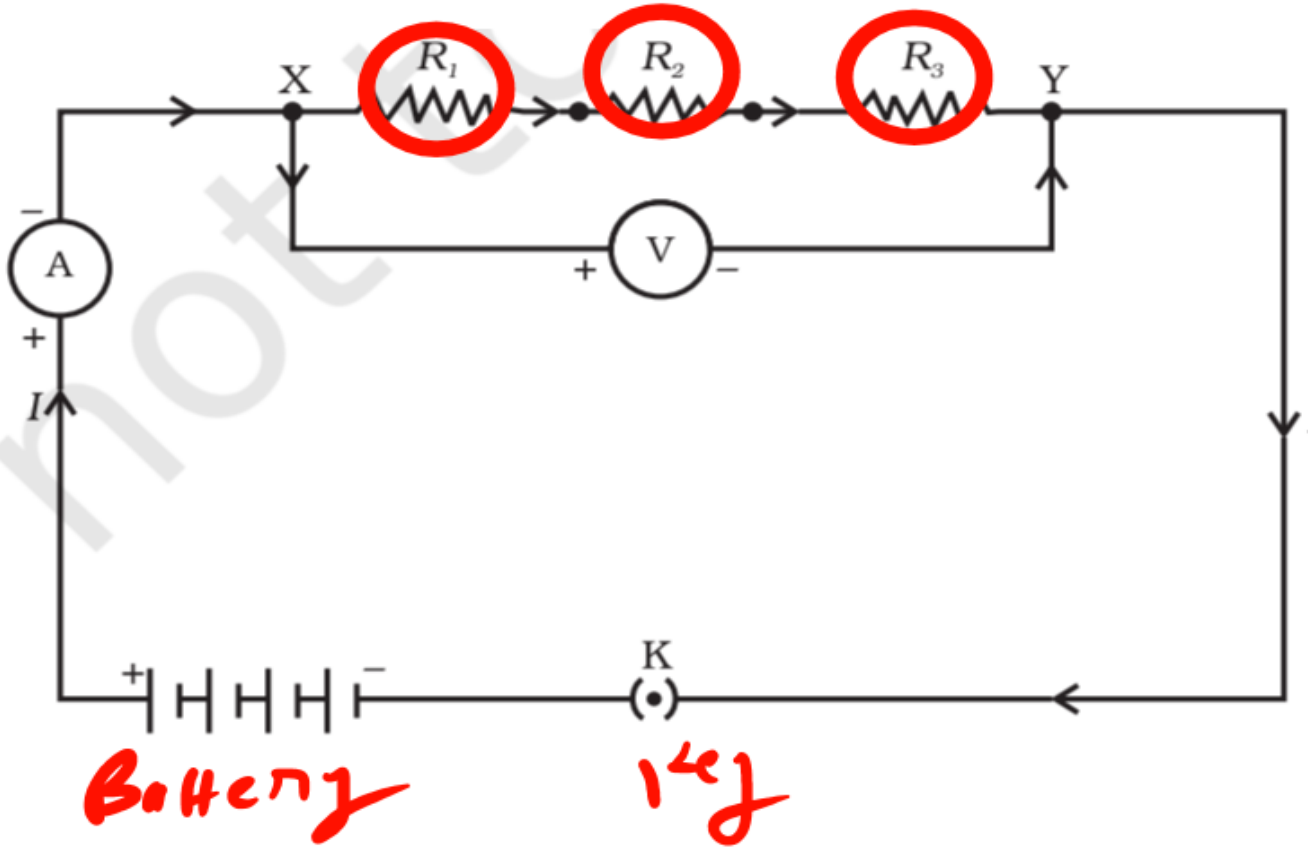
$$I \propto A$$

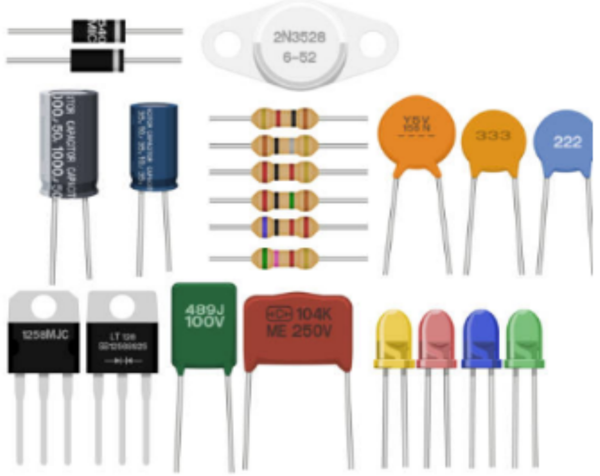
So $I_2 > I_1$ Ans

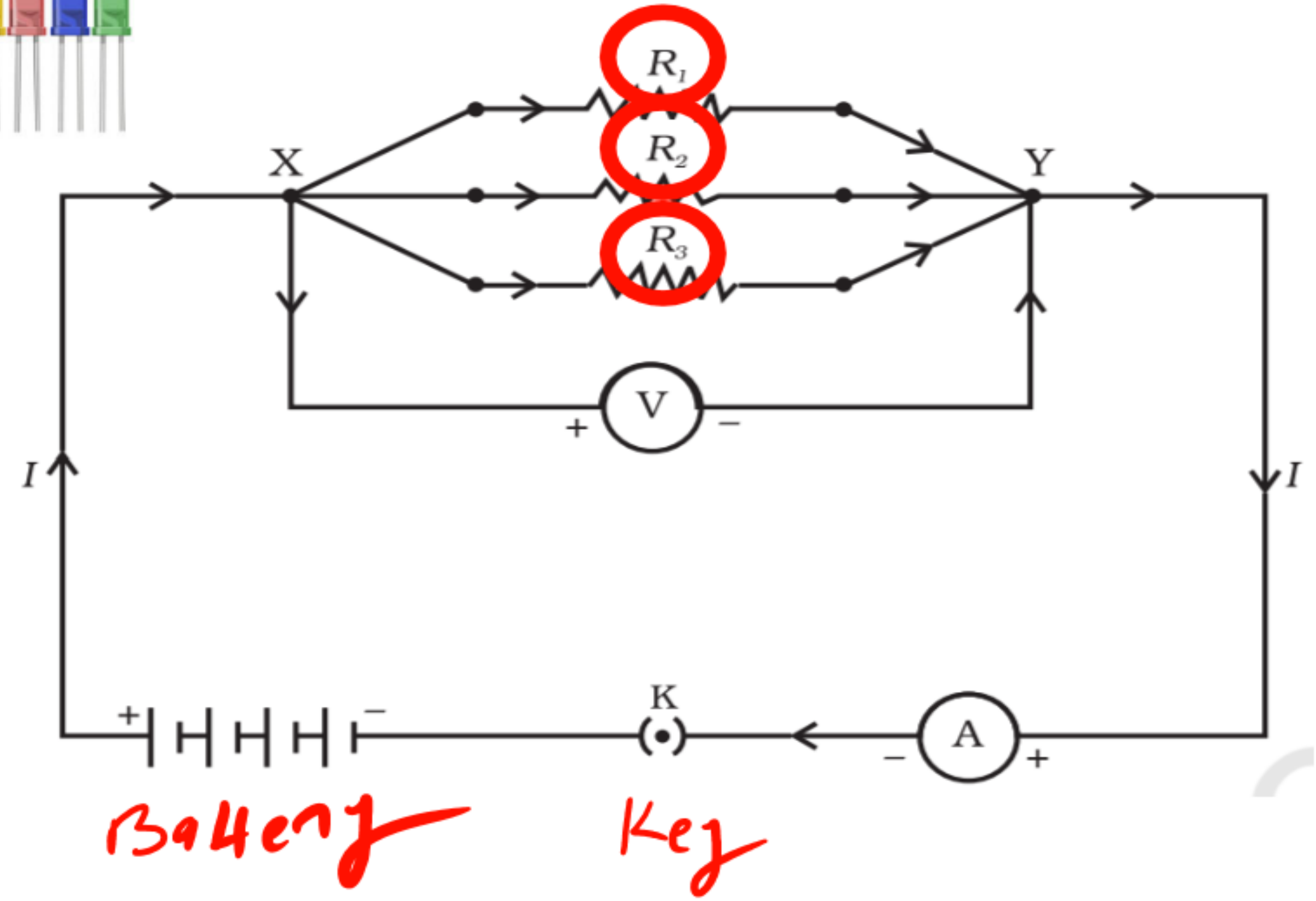
Connection of resistor

In Series

In parallel

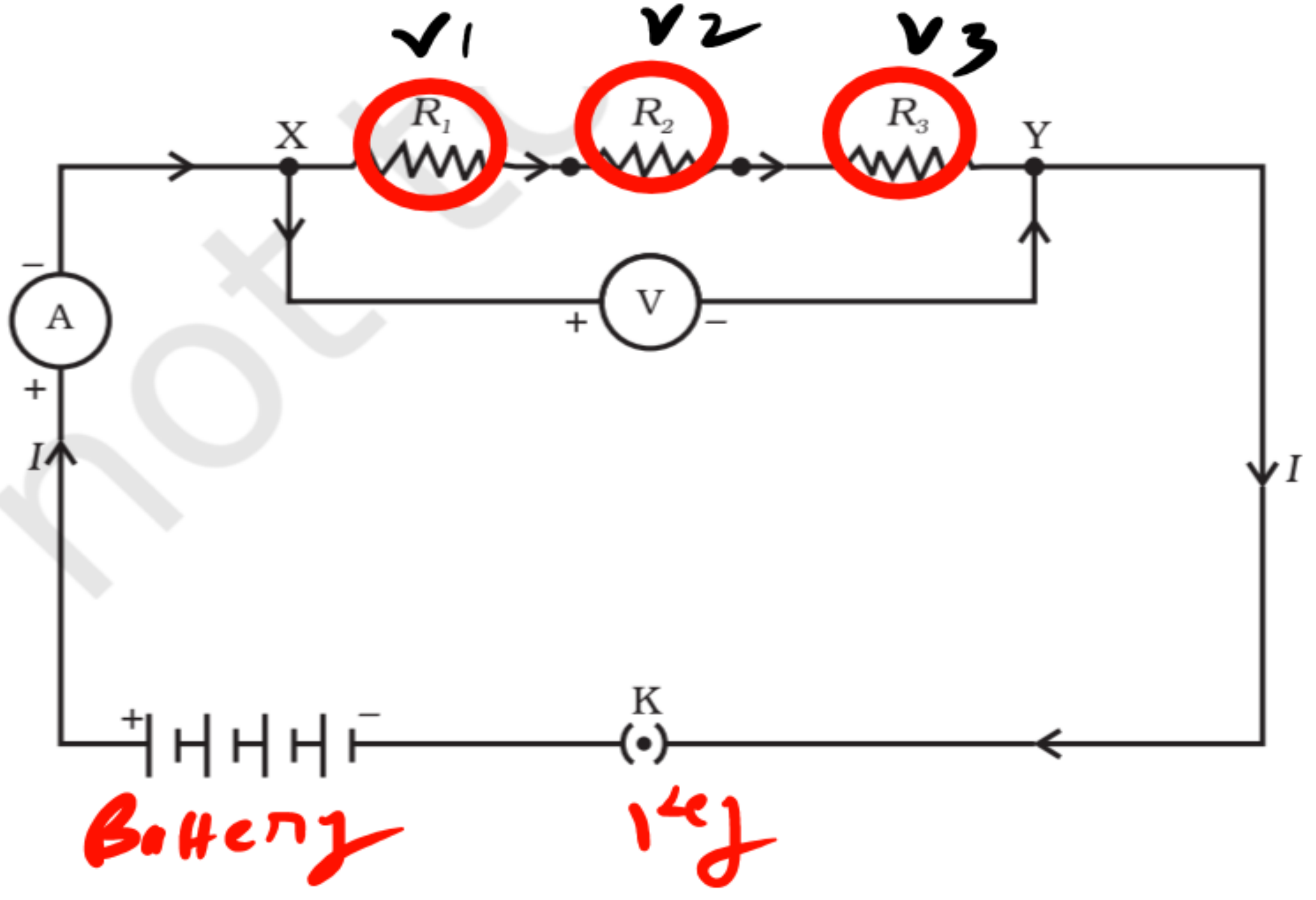






$\because V = IR$

$V_1 = IR_1$
$V_2 = IR_2$
$V_3 = IR_3$



$V = V_1 + V_2 + V_3$

$IR = IR_1 + IR_2 + IR_3$

$\cancel{I}R = \cancel{I}(R_1 + R_2 + R_3)$

$R = R_1 + R_2 + R_3$

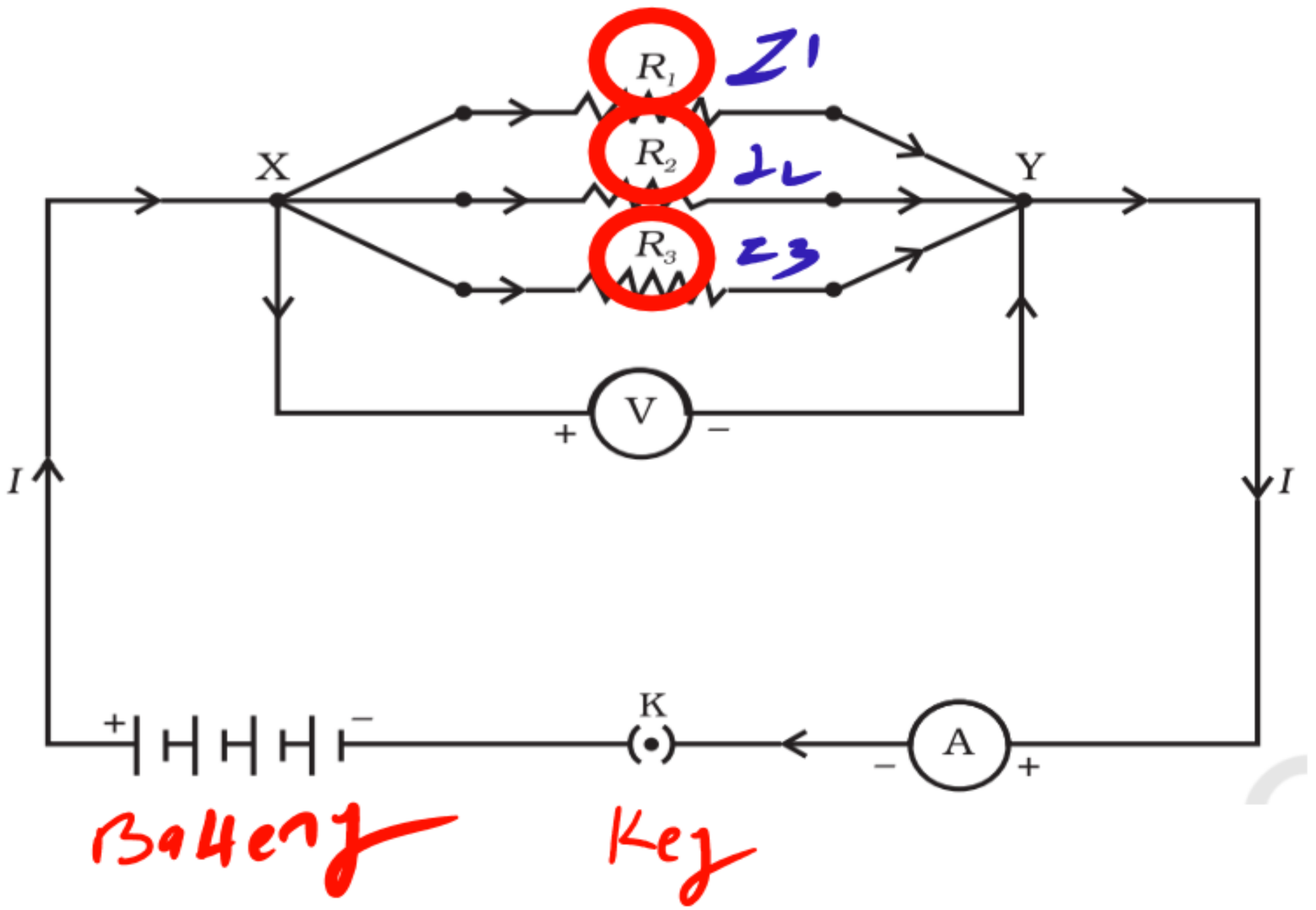
$R_{net} = R_1 + R_2 + R_3 + \cdots R_n$

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

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$



$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

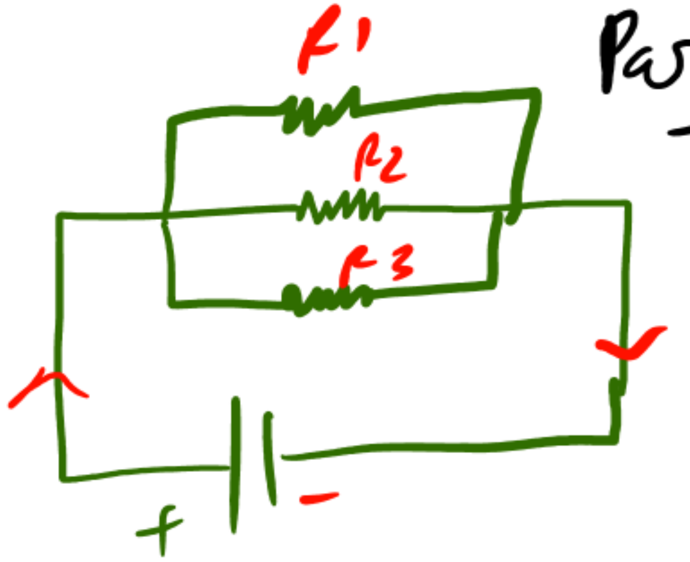
$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

for two resistor —

$$R_{net} = \frac{R_1 R_2}{R_1 + R_2}$$

Parallel



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$$

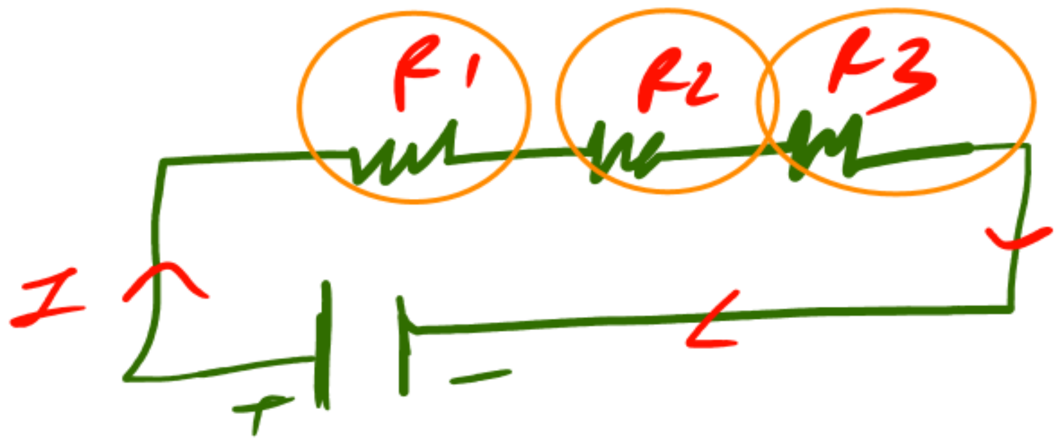
$$\frac{1}{R} = \frac{6+3+2}{12}$$

$$\frac{1}{R} = \frac{11}{12}$$

$$R = \frac{12}{11}\,\Omega$$

$R\downarrow \quad I\uparrow$

Series



$$R = R_1 + R_2 + R_3$$

$$R = (2+4+6)\,\Omega$$

$$R = 12\,\Omega$$

$R\uparrow \quad I\downarrow$

$R_S > R_P$

Series → R_S Parallel → R_P

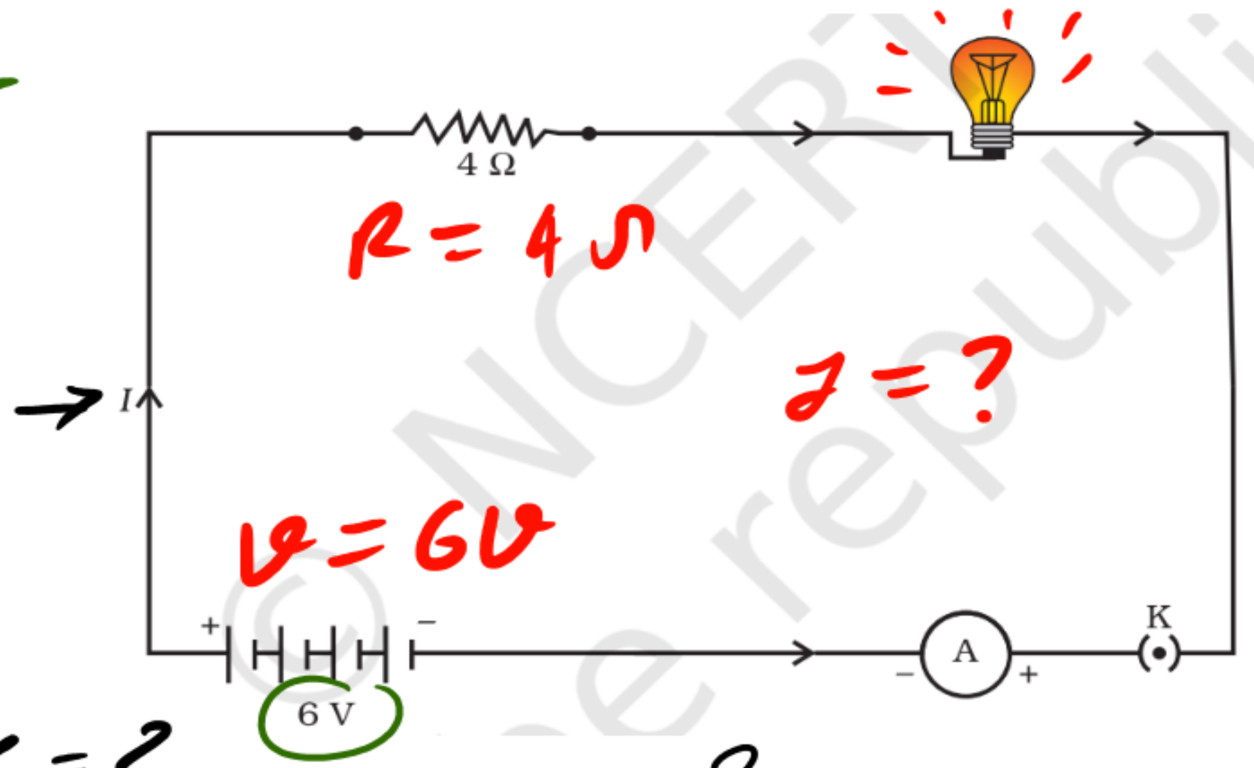
এক্সট্রা জ্ঞান —

	Series circuit	Parallel circuit
(1) Current flow	Current is the same in each component $I_1 = I_2 = I_3 = I$	Current is split between branches $I = I_1 + I_2 + I_3$
(2) Voltage	Voltage is the sum of the voltage drops across each component $V = V_1 + V_2 + V_3$	Voltage is the same across each component $V_1 = V_2 = V_3 = V$
(3) Resistance	Resistance increases with more resistors $R_{max} = R_1 + R_2 + R_3$	Resistance decreases with more resistors $R_{min} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
(4) Circuit breakdown	If one component breaks, the whole circuit stops working (doesn't better)	If one component breaks, the other components keep working (Better)

Parallel	Series
• V is constant → (Same)	• V is variable
$V_1 = V_2 = V_3 = V$	$V_1 + V_2 + V_3 = V$
• I is variable ↳ (different)	• I is constant
$I_1 + I_2 + I_3 = I$	$V_1 = V_2 = V_3 = V$

Example 11.7

An electric lamp, whose resistance is 20 Ω, and a conductor of 4 Ω resistance are connected to a 6 V battery (Fig. 11.9). 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.



(1)

$R_1 = 20\,\Omega$ (Bulb)

$R_2 = 4\,\Omega$ (conductor)

$R_T = R_1 + R_2$

$R_T = (20+4)\,\Omega$

$R_T = 24\,\Omega$

(2) Series

$I = ?$

$R = 24\,\Omega$

$V = 6$

$V = IR$ [acc to ohm's law]

$6 = I \times 24$

$I = \frac{1}{4} = 0.25$

$I = 0.25\,A$

for conductor –

$V = IR$

$V = \frac{1}{4} \times 4$

$V = 1V$

for lamp –

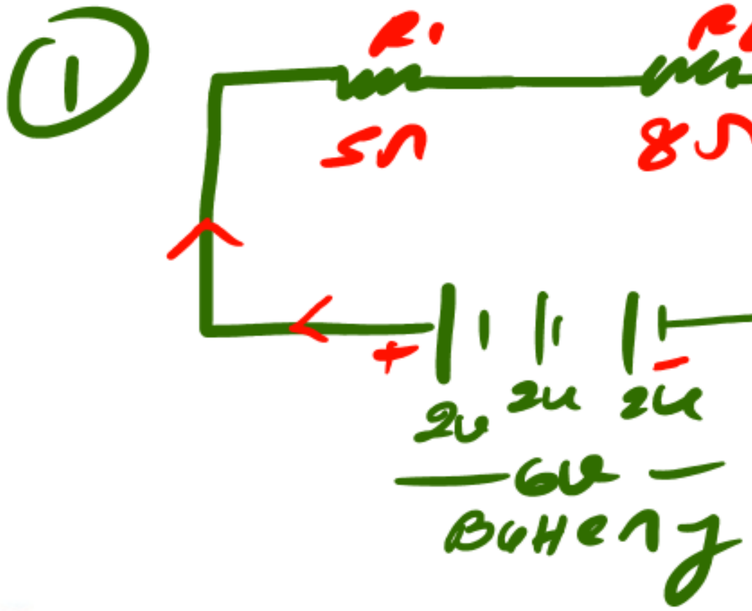
$V = IR$

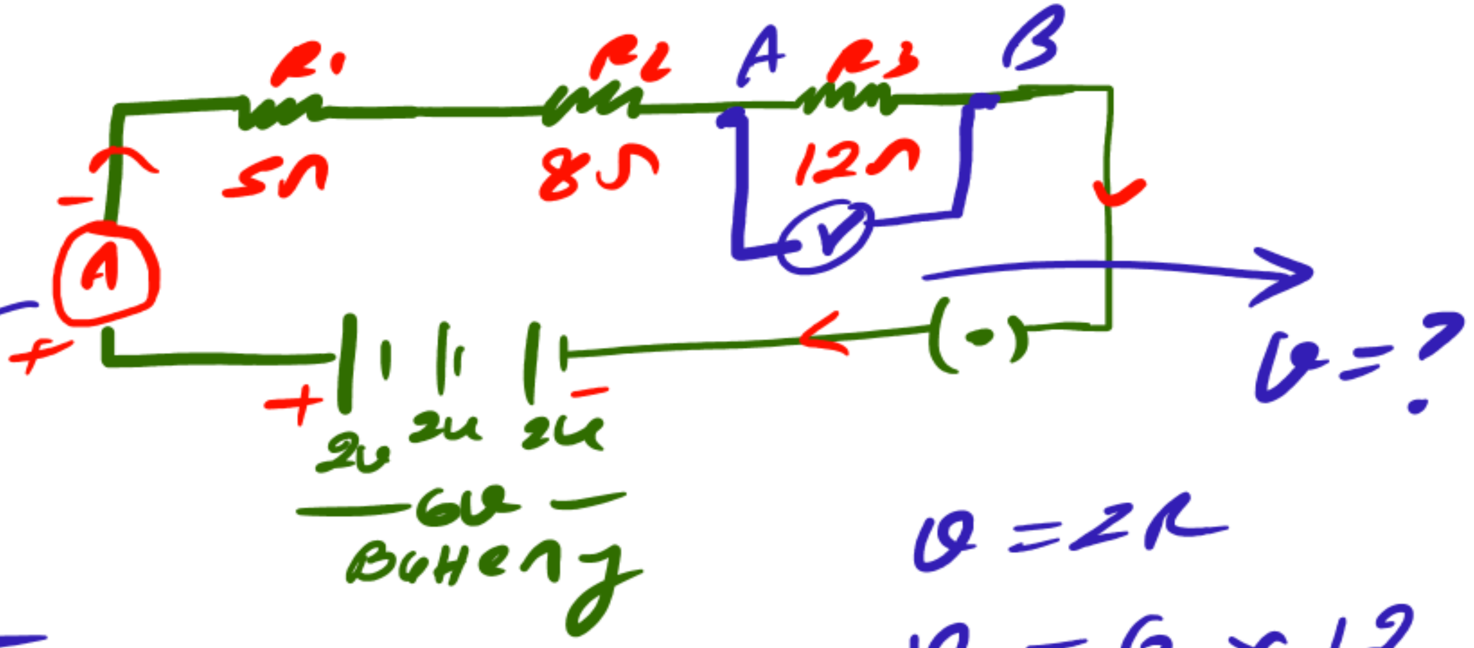
$V = \frac{1}{4} \times 20$

$V = 5V$

QUESTIONS

1. Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, an 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.
2. Redraw the circuit of Question 1, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the readings in the ammeter and the voltmeter?





$I = ?$

$\therefore V = IR$

$6 = I \times 25$

$I = \frac{6}{25} A$

$V = IR$

$V = \frac{6}{25} \times 12$

$V = \frac{72}{25} V$

Example 11.8

In the circuit diagram given in Fig. 11.10, suppose the resistors R_1, R_2 and 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) the total current in the circuit, and (c) the total circuit resistance.

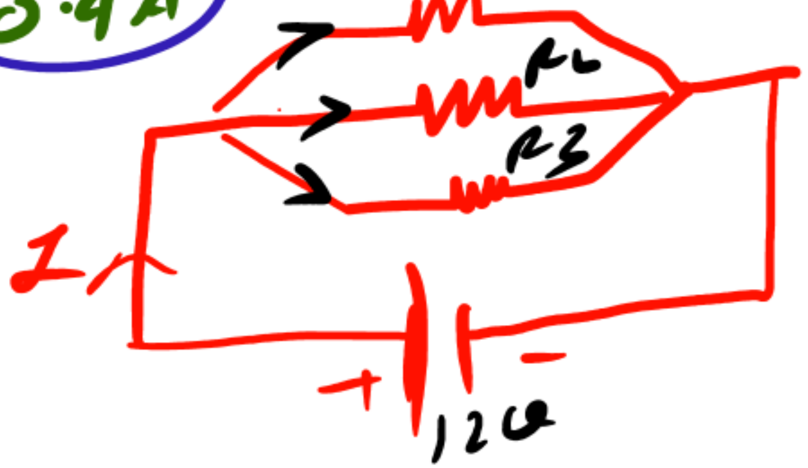
$R_1 = 5\,\Omega$
$R_2 = 10\,\Omega$
$R_3 = 30\,\Omega$
$V = 12\,V$

(a) for R_1 —
$V = I_1 R_1$
$12 = I_1 \times 5$
$I_1 = \frac{12}{5} = 2.4$

for R_2 —
$V = I_2 R_2$
$12 = I_2 \times 10$
$I_2 = \frac{12}{10} = 1.2\,A$

for R_3 —
$V = I_3 R_3$
$12 = I_3 \times 30 = 0.4\,A$

$I_3 = \frac{12}{30} = 0.4\,A$



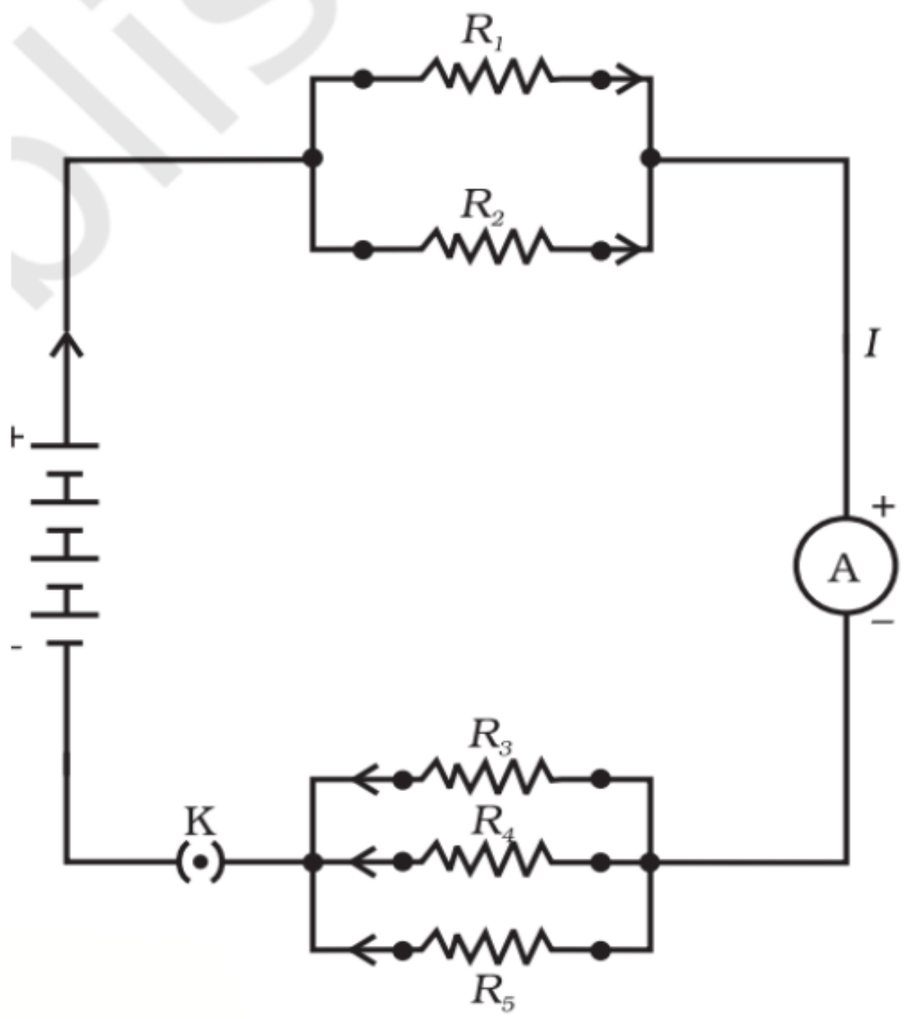
(b) Total current
$I_1 + I_2 + I_3 = I$
$I = 2.4 + 0.4 + 1.2$
$I = 4\,A$

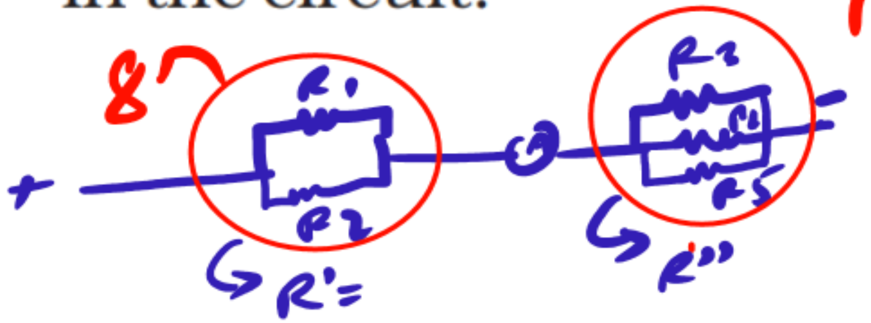
(c) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
$\frac{1}{R} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30}$
$\frac{1}{R} = \frac{6+3+1}{30}$
$\frac{1}{R} = \frac{10}{30}$
$R = 3\,\Omega$

$I = 4\,A$
$V = 12\,V$
$R = 3\,\Omega$
$I = \frac{V}{R}$
$I = \frac{12}{3} = 4$
$I = 4\,A$

Example 11.9

If in Fig. 11.12, $R_1 = 10\ \Omega$, $R_2 = 40\ \Omega$, $R_3 = 30\ \Omega$, $R_4 = 20\ \Omega$, $R_5 = 60\ \Omega$, 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.





$$R' = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R' = \frac{400}{50} = 8$$

$$R' = 8\ \Omega$$

$$\frac{1}{R''} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}$$

$$\frac{1}{R''} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60}$$

$$\frac{1}{R''} = \frac{2+3+1}{60}$$

$$\frac{1}{R''} = \frac{6}{60} = \frac{1}{10}$$

$$R'' = 10\ \Omega$$

$$R_{Total} = R' + R''$$

$$= (8 + 10)\ \Omega$$

$$= 18\ \Omega$$

Q U E S T I O N S

1. Judge the equivalent resistance when the following are connected in parallel – (a) 1 Ω and 10^6 Ω, (b) 1 Ω and 10^3 Ω, and 10^6 Ω.
2. An electric lamp of 100 Ω, a toaster of resistance 50 Ω, and a water filter of resistance 500 Ω are connected in parallel to a 220 V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances, and what is the current through it?
3. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?
4. How can three resistors of resistances 2 Ω, 3 Ω, and 6 Ω be connected to give a total resistance of (a) 4 Ω, (b) 1 Ω?
5. What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?

ELECTRIC POWER

Electric power is the rate of transfer of electrical energy within a circuit. Its SI unit is the watt, the general unit of power, defined as one joule per second.

Electrical power is denoted by 'P'.

Electrical power = $\frac{\text{work}}{\text{time}}$

$$P = \frac{W}{t}$$ → J/s or Js^{-1}

- 1 kilowatt = 1000 watt
- 1 kWh = 3.6×10^6 J

SI unit of (P) is
- large unit → kilowatt
- small unit → watt (W)

Derivation of Power (P)

Power = volt × current

$P = VI$ → 1st formula

$\because V = IR$

$P = (IR) \times I$

$P = I^2 R$ → 2nd formula

$\because V = IR$

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

$P = V\left(\frac{V}{R}\right)$

$P = \frac{V^2}{R}$ → 3rd formula

1 kWh = ? Joule

$\because$ 1 kW = 1000 watt

$\because$ 1 h = 60 × 60 = 3600 second

= 1000 × 3600

= 3600000 J

$= 3.6 \times 10^6$ J

$1\ kWh = 3.6 \times 10^6$ J

More to Know!

Many people think that electrons are consumed in an electric circuit. This is wrong! We pay the electricity board or electric company to provide energy to move electrons through the electric gadgets like electric bulb, fan and engines. We pay for the energy that we use.

This statement is correct; electrons are not "consumed" in an electric circuit; instead, they simply move through the circuit, transferring energy from the power source to the devices like bulbs, fans, and engines, and it's this energy transfer that we pay for when we receive an electricity bill, not the electrons themselves.

Electrical energy (E) -

Energy = power × time

$$E = P \times t$$

P → In large unit (KW)

t → hour (h)

Note -

1 kWh is also known as unit.

$$\text{Unit} = \frac{\text{power} \times \text{no. of Appli.} \times \text{day} \times \text{hour} \times \text{cost}}{1000}$$

Example 11.12

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

$V = 220 V$

$I = 0.50 A$

Power of the bulb (P) = ?

$\because P = V \times I$

$P = 220 \times 0.5$

$P = 22 \times 5$

$P = 110$ watt

Example 11.13

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?

P = 400 W

cost = ?

∴ total cost = $\frac{\text{power} \times 8 \times 30 \times 3}{1000}$

$= \frac{400 \times 8 \times 30 \times 3}{1000}$

$= 32 \times 9$

$= ₹ 288$

QUESTIONS

1. What determines the rate at which energy is delivered by a current?
2. An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

→ $P = V \times I$

$P = 220 \times 5$

$P = 1100$ watt

→ $E = P \times t$

$\frac{1100}{1000} \times 2$

$E = \frac{11}{5} = 2.2$ J

(2) $P = ?$

$I = 5A$

$V = 220V$

$t = 2h$

$E = ?$

HEATING EFFECT OF ELECTRIC CURRENT

The law implies that heat produced in a resistor is (i) directly proportional to the square of current for a given resistance, (ii) directly proportional to resistance for a given current, and (iii) directly proportional to the time for which the current flows through the resistor. In practical situations, when an electric appliance is connected to a known voltage source,

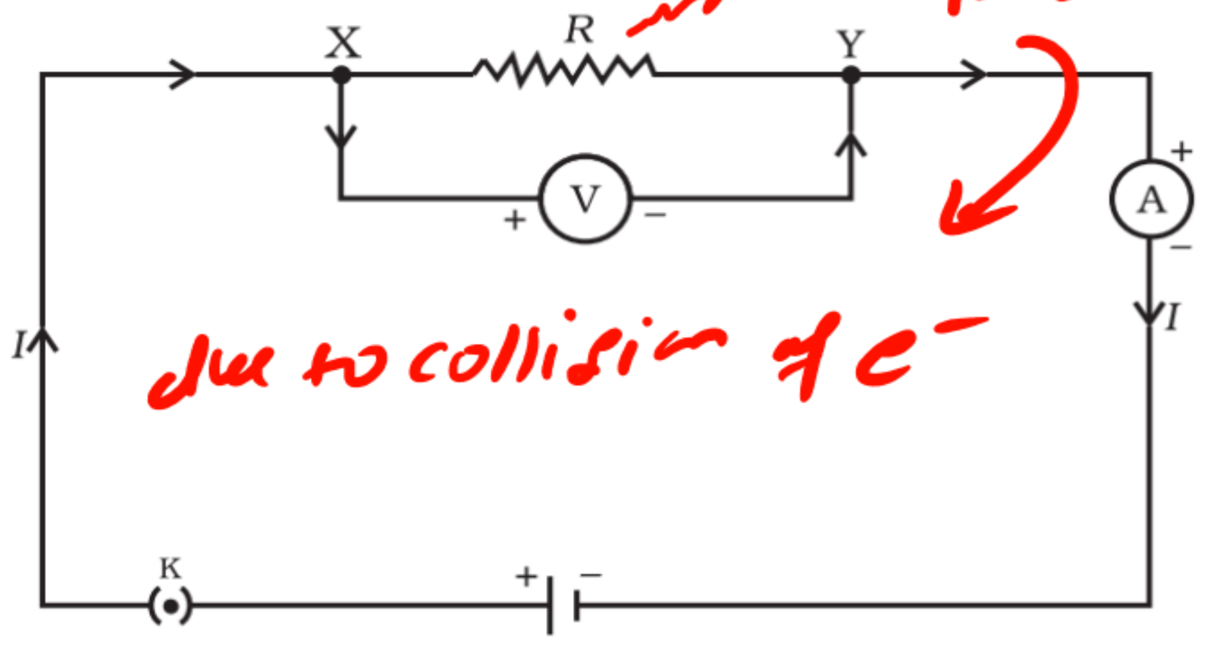


Figure 11.13
A steady current in a purely resistive electric circuit

H is directly pro. to square of current

$H \propto I^2$ — (i)

H is directly pro. to Resistance

$H \propto R$ — (ii)

H is directly pro. to time

$H \propto t$ — (iii)

from (i), (ii) and (iii)

$H \propto I^2 R t$

$H = K I^2 R t$

$K = 1$

$$H = I^2 R t$$

This is known as Joule's law of heating.

Practical Applications of Heating Effect of Electric Current

The electric laundry iron, electric toaster, electric oven, electric kettle and electric heater are some of the familiar devices based on Joule's heating.

oven

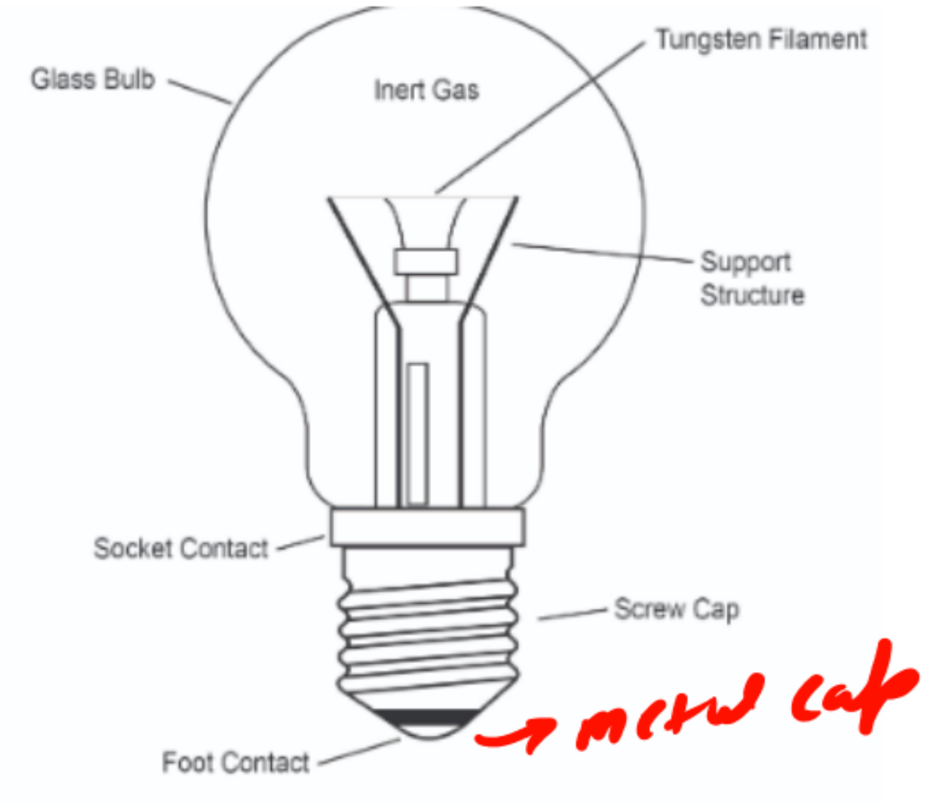
Electric kettle

Toaster

Iron (Press)

These are based on the Joule's law of heating.

The electric heating is also used to produce light, as in an electric bulb. Here, the filament must retain as much of the heat generated as is possible, so that it gets very hot and emits light. It must not melt at such high temperature. A strong metal with high melting point such as tungsten (melting point 3380°C) is used for making bulb filaments. The filament should be thermally isolated as much as possible, using insulating support, etc. The bulbs are usually 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 of it is in the form of light radiated.



- filament → Tungsten → high melting point
- Inert gas → Argon gas
- produced → Bright light
- melting point → 3380°c

Another common application of Joule's heating is the fuse used in electric circuits. It protects circuits and appliances by stopping the flow of any unduly high 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 appropriate melting point, for example aluminium, copper, iron, lead etc. If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases. This melts the fuse wire and breaks the circuit. The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends. The fuses used for domestic

A fuse is a safety device that protects electrical circuits from damage caused by excessive current. Fuses can also be used in hydraulic systems and explosives.

Chapter bahut acche se cover ho gya hai bas ab aap sabhi ko apne notes complete karne hai aur sabhi example and numericals ko solve karna hai jisase apki is chapter par command acche se ho jaye.