



CLASS – X (PHYSICS)

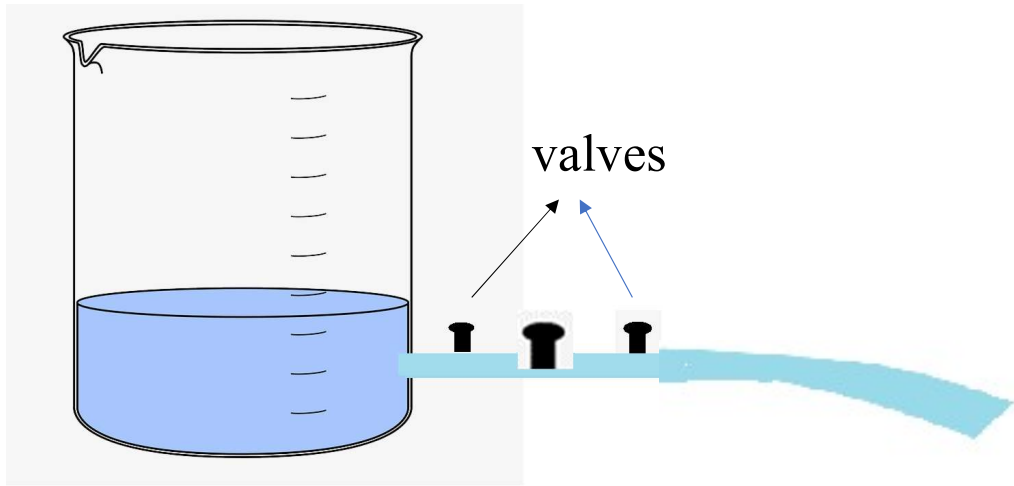
CLASS-X
CHAPTER-12
(ELECTRICITY)

Theory – Part 2

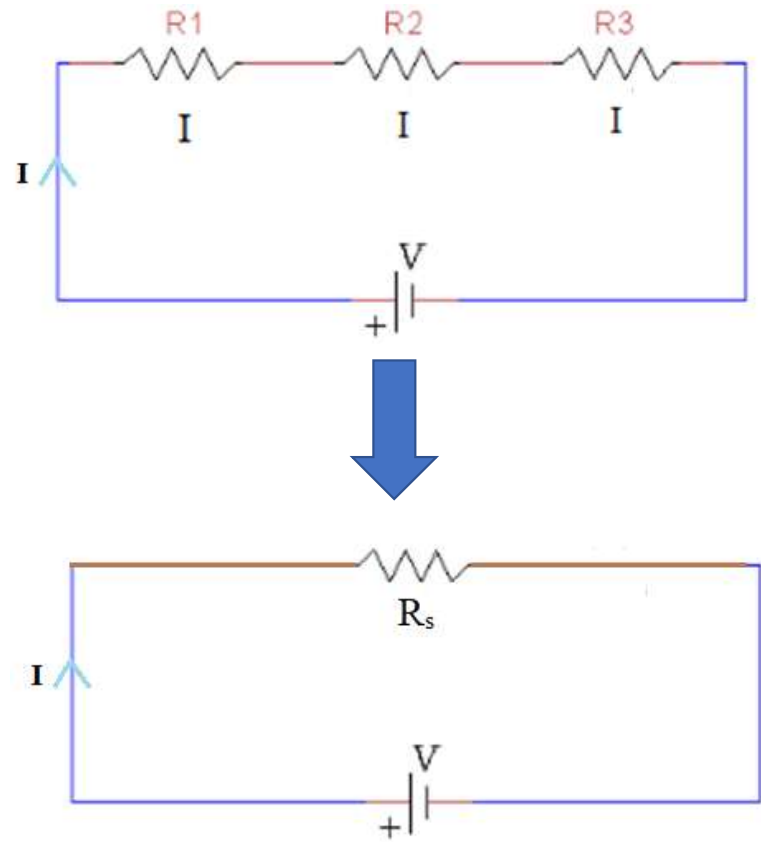
So far we have learnt:

- Charge (Q)
- Current (I)
- Potential difference (V)
- Open circuit and closed circuit
- Relation between V and I (OHM'S LAW)
- Factors on which the resistance of a conductor depend
- Resistance
- Resistivity

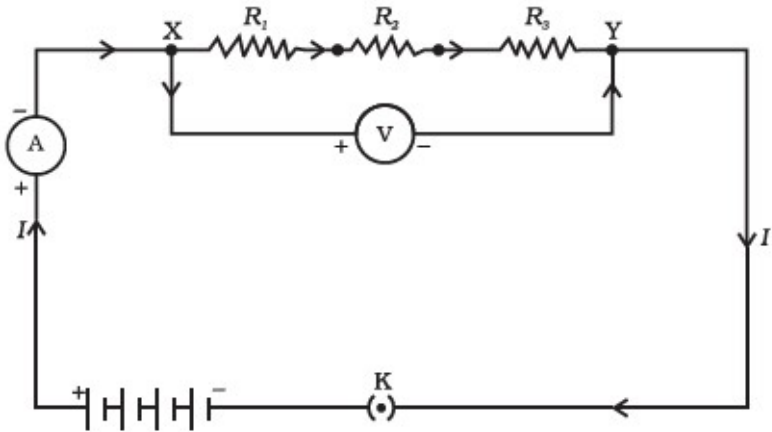
RESISTORS IN SERIES



$$R_s = R_1 + R_2 + R_3$$



RESISTORS IN SERIES



Place an ammeter at different positions in the circuit.

Will there be any change in the value of current through the ammeter?

Observation: We will observe that the value of the current in the ammeter is the same, independent of its position in the electric circuit.

Conclusion: Current is the same in every part of the circuit or the same current through each resistor.

- Let the voltmeter reading across the ends X and Y it be V .
- Now insert the voltmeter across the ends X and P of the first resistor. Let it be V_1 .
- Next insert the voltmeter across the ends Q and S of the first resistor. Let it be V_2 .
- Then insert the voltmeter across the ends T and Y of the first resistor. Let it be V_3 .

You will observe that the potential difference V is equal to the sum of potential differences V_1 , V_2 , and V_3 .

$$V = V_1 + V_2 + V_3$$

Derivation of Effective Resistance for series combination of resistors

In a series circuit,

(a) the current I is the same in all parts of the circuit, and

(b) the total potential difference across a combination of resistors in series is equal to the sum of potential difference across the individual resistors.

$$V = V_1 + V_2 + V_3 \dots\dots\dots(1)$$

From Ohm's law, $V = IR \dots\dots\dots(2)$

On applying Ohm's law to the three resistors separately, we further have

$$V_1 = IR_1 \dots\dots\dots(3)$$

$$V_2 = IR_2 \dots\dots\dots(4)$$

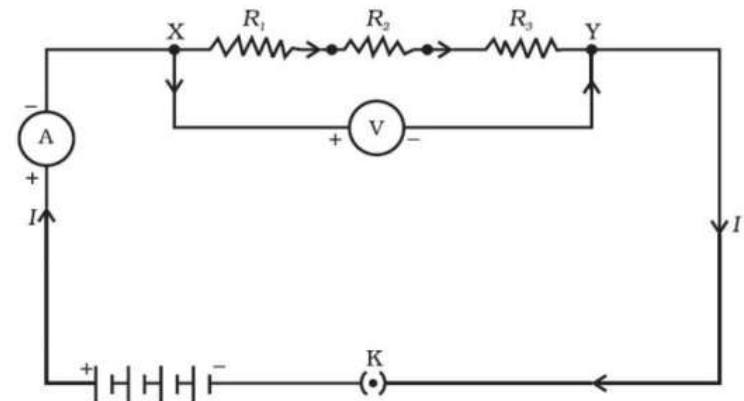
$$V_3 = IR_3 \dots\dots\dots(5)$$

Substituting (2), (3),(4),(5) in(1),

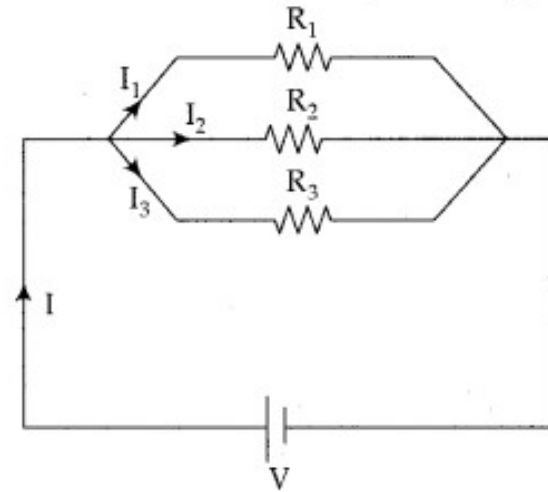
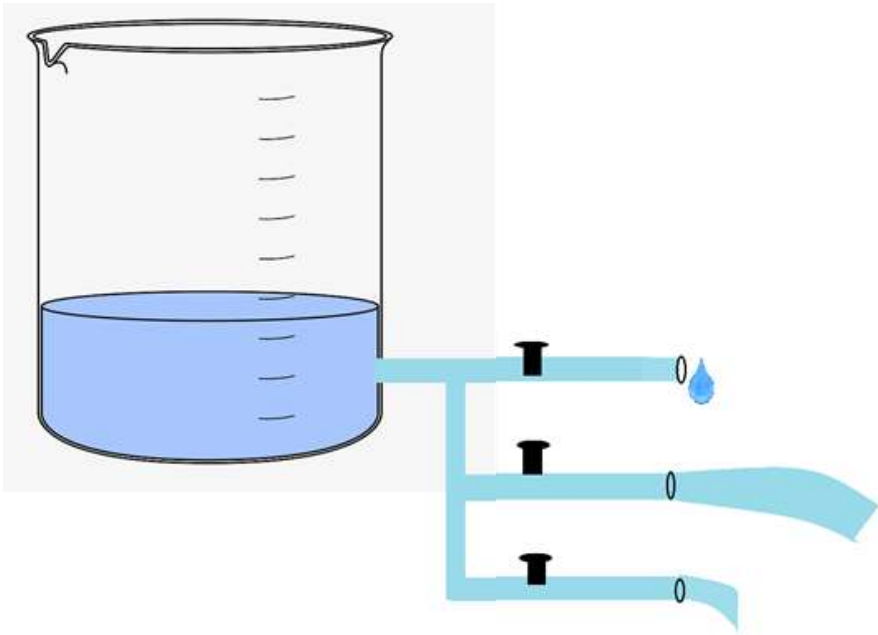
$$IR = IR_1 + IR_2 + IR_3$$

$$I (R) = I (R_1 + R_2 + R_3)$$

$$R_s = R_1 + R_2 + R_3$$

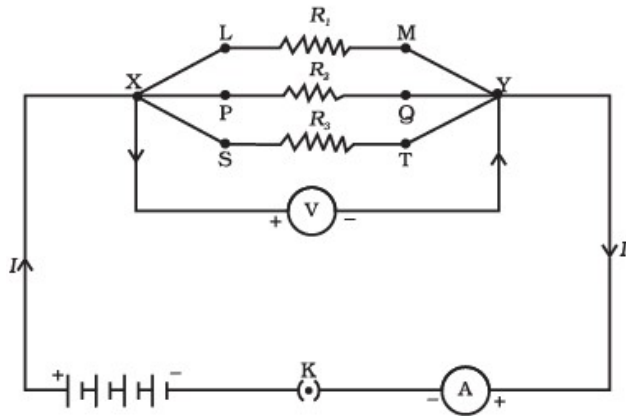


RESISTORS IN PARALLEL

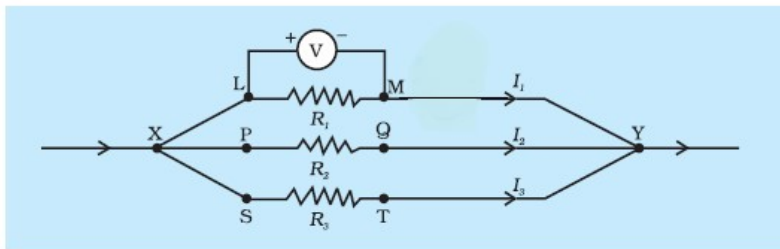


- Potential difference is same across each resistor
- Current is not same
and $I = I_1 + I_2 + I_3$

RESISTORS IN PARALLEL

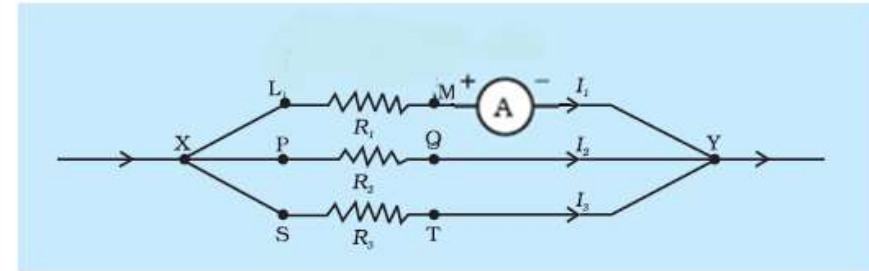


- Plug the key and note the ammeter reading. Let the current be I .
- Also take the voltmeter reading. It gives the potential difference V , across the combination.



- Now check the potential difference across each resistor by connecting the voltmeter across each individual resistor.

Observation: It is observed it is also V



- Insert the ammeter in series with the resistor R_1 . Note the ammeter reading, I_1 .
- Next Insert the ammeter in series with the resistor R_2 . Note the ammeter reading, I_2 .
- Similarly, measure the current through R_3 . Let these be I_3 .

Observation: It is observed that the total current I , is equal to the sum of the separate currents through each branch of the combination.

$$I = I_1 + I_2 + I_3$$

Derivation of Effective Resistance for Parallel combination of resistors

In a parallel circuit:

(a) the potential difference V , across each resistor is same

(b) the total current I , is equal to the sum of the separate currents through each branch of the combination.

$$I = I_1 + I_2 + I_3 \dots \dots \dots (1)$$

Let R_p be the equivalent resistance of the parallel combination of resistors. By applying Ohm's law to the parallel combination of resistors, we have

$$I = V/R_p \dots \dots \dots (2)$$

On applying Ohm's law to each resistor, we have

$$I_1 = \frac{V}{R_1} \dots \dots \dots (3)$$

$$I_2 = \frac{V}{R_2} \dots \dots \dots (4)$$

$$I_3 = \frac{V}{R_3} \dots \dots \dots (5)$$

Substituting (2), (3), (4), (5) in (1),

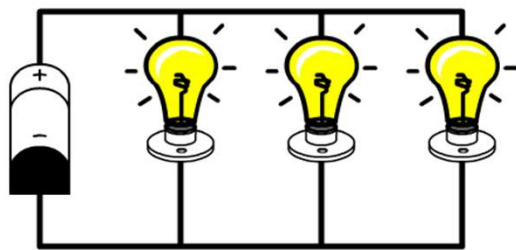
$$\frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

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

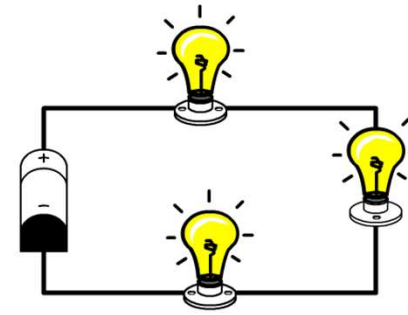
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

	DISADVANTAGES OF SERIES COMBINATION OF RESISTANCES	ADVANTAGES OF PARALLEL COMBINATION OF RESISTANCES
If one component fails	If one component fails, the circuit is broken and none of the components works.	If one component fails, then other appliances will not be affected.
On/off switch	All the electrical appliances will have only one switch due to which they cannot be turned on/off separately.	Each electrical appliance has its own switch due to which they can be turned on/off separately.
Current needs of appliances	Different electric appliances have different resistances and hence they require different amount of current and a series circuit provides same current to all the resistors.	Different electric appliances have different resistances and hence they require different amount of current and a parallel circuit provides the required amount of current.
Potential Difference across each electrical component	The appliances do not get the same voltage (220V) as that of power supply line because voltage is shared by all the appliances.	Each appliance gets the same voltage (220V) as that of power supply line.

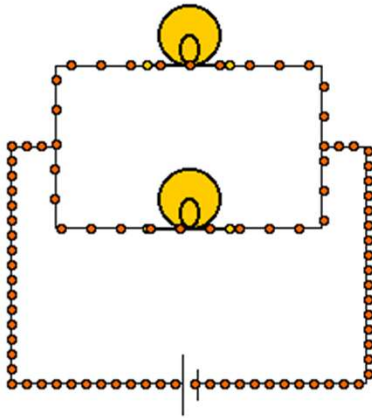
Advantages of Parallel over Series Combination/ Disadvantages of series combination



Parallel Circuit



Series Circuit



Put on your thinking caps!



- A battery has to keep expending its energy to maintain the current.
- Where does this energy go?
- A part may be consumed into useful work
- and some part in the form of heat to raise the temperature of the gadget.
- Do you think it is wastage of energy?
- But, this heat can be useful too at times?

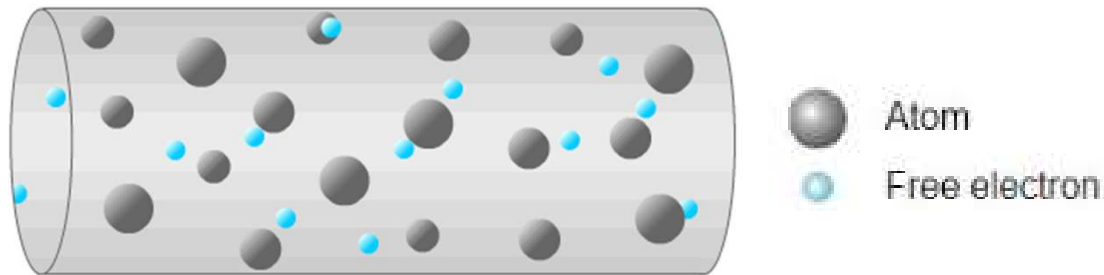
HEATING EFFECT OF ELECTRIC CURRENT



Joule's Heating

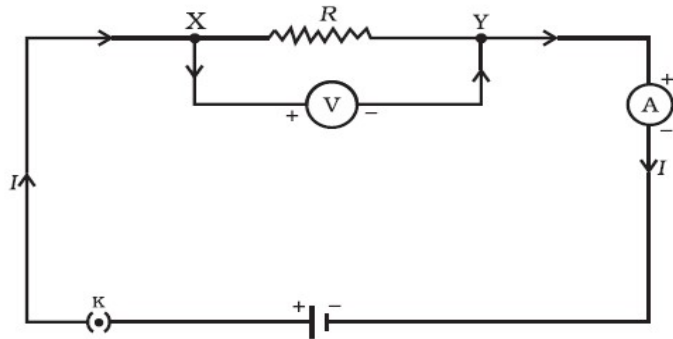
- James Prescott Joule
- S.I unit of Heat?
 - Joule (J)

What causes Joule's Heating?



When current flows through an electric circuit, the collision between the electrons and atoms of wire **causes heat** to be generated.

Amount of heat produced in a conductor



Consider a current I flowing through a resistor of resistance R . Let the potential difference across it be V . Let t be the time during which a charge Q flows across.

The work done in moving the charge Q is given by:

$$W = Q V \dots\dots\dots(1) \quad (\because V = \frac{W}{Q})$$

Now, $Q = I t \dots\dots\dots(2) \quad (\because I = \frac{Q}{t})$

According to Ohm's law,
 $V = I R \dots\dots\dots(3)$

Putting the values of (2) and (3) in (1)

$$W = I t \times I R$$

$$W = I^2 R t$$

This energy gets dissipated in the resistor as heat. Thus for a steady current I , the amount of heat H produced in time t is

$$H = I^2 R t \quad \longrightarrow \quad \text{Joule's Law of Heating}$$

Joule's Law of Heating

$$H = I^2 R t$$

Joule's Law of Heating, states that the heat produced in a resistor is directly proportional to the

- Square of the current in the resistor, $H \propto I^2$
- Resistance of the resistor, $H \propto R$
- Time for which the current flows through the resistance, $H \propto t$

OTHER FORMULAE FOR HEAT

- We know, $H = I^2 R t \dots\dots\dots(1)$

$$I = V/R$$

Substituting I in (1)

$$H = \left(\frac{V}{R} \right)^2 R t$$

$$H = \frac{V^2}{R^2} R t = \frac{V^2}{\cancel{R} \times R} t$$

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

- We know, $H = I^2 R t \dots\dots\dots(1)$

$$R = V/I$$

Substituting R in (1)

$$H = I^2 \left(\frac{V}{I} \right) t$$

$$H = \cancel{I} \times I \frac{V}{\cancel{I}} t$$

$$H = V I t$$

$$H = I^2 R t = \frac{V^2 t}{R} = V I t$$

PRACTICAL APPLICATIONS OF THE JOULE'S LAW OF HEATING

- The electric laundry iron, electric toaster, electric oven, electric kettle and electric heater
- Electric bulb
- Fuse

FUSE

- **Construction :**

It consists of a piece of wire made of an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc.

Commonly used fuse wire: an alloy of lead and tin.

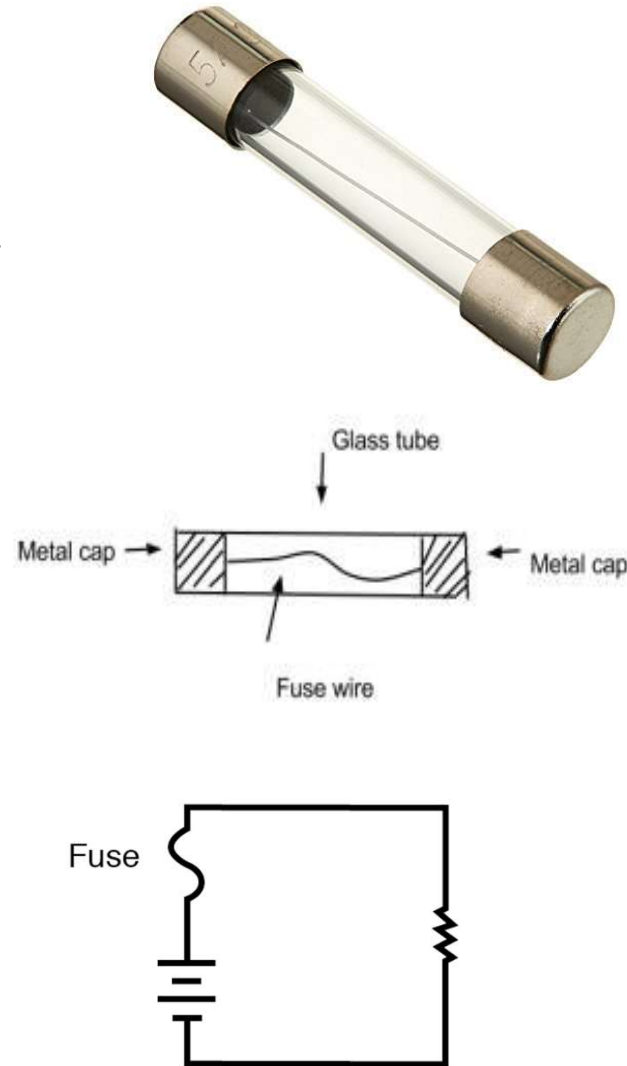
The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends

- **Working:**

If a current larger than the specified value flows through the circuit, the temperature of the fuse wire increases as more heat is produced due to high resistance. This melts the fuse wire and breaks the circuit.

- **Function:**

It protects circuits and appliances by stopping the flow of any unduly high electric current.





What does this 'W' represent?

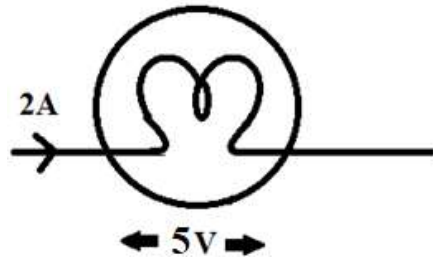
- W also called Watt is the S.I. unit of Electric power.
- Power a measure of how much energy is consumed or delivered in unit time.
- i.e. $\text{Power} = \frac{\text{Energy}}{\text{Time}}$
- $\text{Watt} = \frac{\text{Joule}}{\text{sec}}$
- So a 60 W bulb means
this bulb consumes 60 J of electrical energy in 1 second

Calculate Electric Power in terms of V and I

- Current: $I = Q/t$

$$2 \text{ A} = \frac{2\text{C}}{1\text{s}}$$

means 2C charge in 1 sec



- Voltage, $V = W/Q$

$$5 \text{ V} = \frac{5\text{J}}{1\text{C}}$$

means 5 J of work by 1 C of charge

- Can you find how much energy is consumed by this bulb in 1 sec?

1 C will deliver 5 J in 1 sec

2C will deliver $5 \times 2 = 10 \text{ J}$ in 1 sec

Therefore, 10 J of energy will be used in 1 sec
i.e 1 W

$$\left(\frac{5 \text{ J}}{\text{C}} \right) \times \left(\frac{2 \text{ C}}{\text{s}} \right) = 10 \text{ J/s} = 10 \text{ W}$$

$$V \times I = P$$

$$\text{or } P = VI$$

if we know power rating of a device and we know voltage across the device we can calculate what current will flow through that device.

ELECTRIC POWER (P)

Definition	The rate of consumption of energy is called power.
Formula	$\text{Power} = \frac{\text{Energy}}{\text{time}} = \frac{\text{Heat}}{\text{time}} = \frac{VIt}{t} = \frac{V^2t}{Rt} = \frac{I^2Rt}{t}$ $P = VI = \frac{V^2}{R} = I^2R$
Definition of SI unit	$P = VI$ 1 watt = 1 volt x 1 ampere 1 watt : It is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1 V.

COMMERCIAL UNIT OF ENERGY (kWh)

$$\begin{aligned} 1 \text{ kW h} &= 1 \text{ kW} \times 1 \text{ h} \\ &= 1000 \text{ W} \times 60 \times 60 \text{ s} \\ &= 1000 \text{ W} \times 3600 \text{ s} \\ &= 3600000 \text{ Ws} \end{aligned}$$

$$1 \text{ kW h} = 3.6 \times 10^6 \text{ J}$$

Reading (D)	Units Consumed [(A-B) x MF] + [(C-D) x MF]	 Scan QR code or enter & ensure UPI ID as making payment through BHIM or  11060008679056000000190
	219	

Current Demand Details / वर्तमान शुल्क का विवरण		
Bill Period 09/09/2019 To 09/10/2019		
Days: 31 Month: 1.0236		
Fixed Charges / स्थायी शुल्क 3.00 * 50.00 * 1.0236 = 153.54.		
# Energy Charges / ऊर्जा शुल्क		
Units	Rate (₹)	Amount (₹)
205 x	3.00	615.00
14 x	4.50	63.00
Total 219		678.00

REASONING
BASED ON
CONCEPTS
LEARNT SO FAR

1. The connecting wires in an electric circuit are made up of copper and aluminium.

or

Copper and aluminium are generally used for electrical transmission lines.

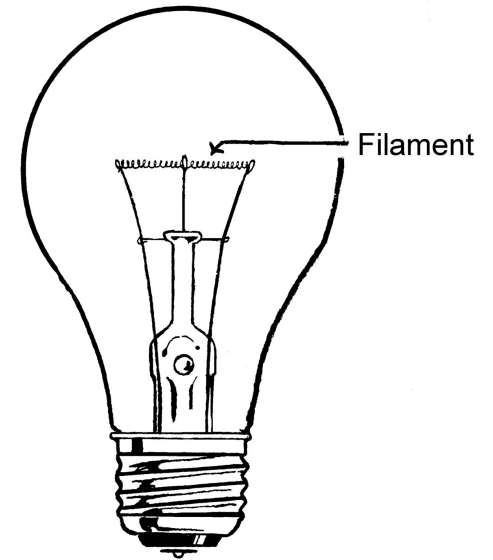
- **Resistivity** of copper and aluminium (pure metals) is **low**. Hence they are good conductors of electricity.
- Silver is a better conductor but it is not used because it is expensive.

$$R = \rho l / A$$

Low Resistivity  Low Resistance  Current flows easily  Good conductor

2. Filament of electric bulb is made of tungsten metal.

- Melting point of tungsten is very high (3380 °C)
- It has high resistance, so a large heat is produced,
($H = I^2 R t$, Joule's law of heating)
- It does not burn (oxidize) even at high temperatures.

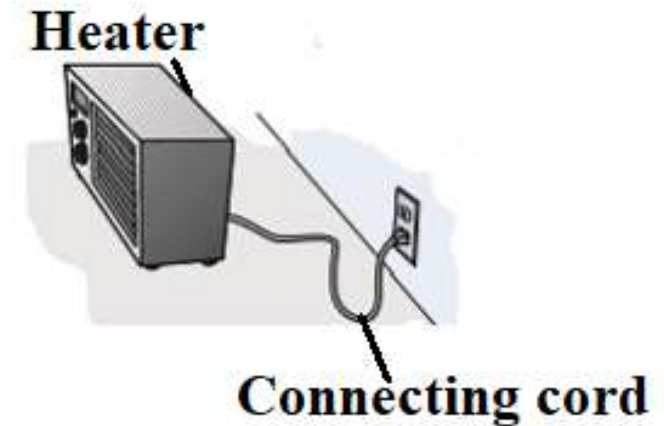


3. Heating elements of electric heating devices, such as bread-toasters and electric irons, are made of an alloy rather than pure metal

- Resistivity of an alloy is more than that of its constituent metals, due to which it produces large amount of heat on passing current
($H = I^2Rt$, Joule's law of heating)
- Alloys generally have high melting point.
- Alloys do not burn (oxidize) even at high temperatures.

4. Why do the wires connecting an electric heater to the mains not glow while its heating element does?

- The wires of the connecting cord of electric heater are made of Cu in which negligible heat is produced due to its extremely low resistivity.
- The heating element of an electric heater is made of nichrome wire. It glows because large amount of heat is produced due to its high resistivity ($H = I^2 R t$)



5. The bulbs are usually filled with chemically inactive nitrogen and argon gases

- to **prolong the life** of filament.

MY TEACHER TOLD ME HOW ELECTRICITY IS MEASURED
AND I WAS LIKE 'WATT'!



HOPE THAT IS NOT THE SCENARIO WITH YOU PEOPLE
NOW.

KEEP STUDYING, ENJOY AND STAY SAFE!