

CBSE Class 10 - Physics

Topic: Electric Power & Joule's Law of Heating (Contd.),

-- Page 2 --

3. Detailed Joule's Law of Heating - Three Factors

Joule's states that the heat produced in a conductor due to current flow depends on three factors:

- $H \approx I^2$ (Heat produced is directly proportional to the square of the current)
→ If current is doubled, heat produced becomes 4 times (since I^2).
- $H \approx R$ (Heat produced is directly proportional to the resistance of the conductor)
→ More resistance → more heat produced for same current & time.
- $H \approx t$ (Heat produced is directly proportional to the time for which current flows)
→ Longer time → more heat produced.

4. Derivation of Joule's Law of Heating

We know, Electric Power, $P = VI$

Also, the work done / energy supplied = Power × Time

$$\therefore H = P \times t = VI \times t$$

From Ohm's Law, $V = IR$

Substituting $V = IR$ in above,

$$H = (IR) \times I \times t = I^2 R t$$

Similarly using $V = IR$, we get $I = V/R$,

$$\therefore H = V \times (V/R) \times t = V^2/R \times t$$

$$\text{Hence, } H = I^2 R t = \frac{V^2 t}{R} = R = VI t$$

5. Commercial Unit of Energy

The SI unit of heat/energy is Joule (J), but it is very small for household/commercial use.

Commercial unit: Kilowatt-hour (kWh)

Definition: → 1 kWh is the energy consumed when a device of 1 kilowatt power is used for 1 hour.

$$\text{Relation: } 1 \text{ kWh} = 3.6 \times 10^6 \text{ Joule}$$

$$\begin{aligned} \text{Derivation: } 1 \text{ kWh} &= 1000 \text{ W} \times 3600 \text{ s} \\ &= 1000 \text{ J/s} \times 3600 \text{ s} = 3,600,000 \text{ J} \end{aligned}$$

Important Points: → $3.6 \times 10^6 \text{ J}$

- 1 unit of electricity = 1 kWh
- Electricity bill is calculated in kWh (units).
- Heat produced is used in devices like electric heater, electric iron, fuse, etc.

* Note: Energy is measured in kWh for practical purposes, while heat is in Joule for scientific calculations.

CBSE Class 10 - Physics

Topic: Electric Power & Joule's Law of Heating

-- Page 1 --

1. Electric Power

Definition: Electric power is the rate at which electrical energy is consumed or delivered in an electric circuit.

→ It tells us how fast electrical energy is used by an appliance.

Formula: $P = VI = I^2R = \frac{V^2}{R}$

Where:

- P = Electric Power (in Watt)
- V = Potential difference / Voltage (in Volt)
- I = Current (in Ampere)
- R = Resistance (in Ohm, Ω)

SI Unit of Power:

→ Watt (symbol: W)

→ 1 Watt = 1 Joule per second ($1 \text{ W} = 1 \text{ J/s}$)

2. Joule's Law of Heating

Definition: → When current flows through a resistor, electrical energy is converted into heat energy. This is known as Joule's heating effect.

Formula: $H = I^2Rt$

Where:

- H = Heat produced (in Joules, J)
- I = Current (Ampere)
- R = Resistance (Ohm, Ω)
- t = Time (seconds, s)

Important Point:

- Higher the current or resistance, more heat is produced.
- This principle is used in electric heater, toaster, bulb filament.

CBSE Class 10 - Physics

Topic: Electric Power & Joule's Law of Heating (Contd.),

-- Page 3 --

6. Power Rating and Voltage Rating of Electric Devices

Every electrical device has a power rating and a voltage rating printed on it.

Example: 100 W, 220 V

- Meaning of 100 W 220 V: $\rightarrow$ the device consumes 100 J of energy per second second when operated at 220 V.
- 220 V is the voltage rating $\rightarrow$ the device is designed to work safely at 220 Volt supply.
- $\rightarrow$ If device is used at 220 V, it will draw power = 100 W.
- If connected to lower/higher voltage, the actual power and current will change.

7. Resistance from Power & Voltage Rating

We can find resistance of the device using its rating:

Formula: $R = \frac{V^2}{P}$

Derivation: From $P = \frac{V^2}{R} \rightarrow R = \frac{V^2}{P}$

For 100 W, 220 V device,

$$R = \frac{(220)^2}{100} = 48400 = 484 \Omega$$

$\therefore$ Resistance = 484 Ω

8. Brightness vs Power - Inverse Relation

Brightness of bulb depends on its power.

- Higher the power rating $\rightarrow$ brighter the bulb (at rated voltage).
- For bulbs of same rated voltage, the bulb with higher Watt glows brighter.
- For same voltage, Resistance $\approx \frac{1}{\text{Power}}$ (since $R = \frac{V}{P}$)
- $\rightarrow$ Higher power = lower resistance = more current = more brightness.
- A 100 W bulb has lower resistance than a 60 W bulb.

9. Connection: Series vs Parallel in Homes

Why appliances are connected in parallel in houses?

- In series: Same current flows through all devices. If one fails, whole circuit breaks. Also each device gets less voltage $\rightarrow$ less power.
- In parallel: Each device gets the same 220 V supply. They work independently.
- If one is switched OFF, If one is switched OFF, others $\times$
- Use wires of proper thickness $\rightarrow$ excessive heating $\rightarrow$ may cause fire (Joule heating).
- Never touch live wire or overloaded circuit with wet hands.
- So household appliances are connected in parallel.
- Total power = $P_1 + P_2 + P_3 + \dots$ (sum of all devices).

10. Safety Points

Important Points:

- $\rightarrow$ Power rating tells energy used per second at rated voltage.
- $\rightarrow$ Always use device at its rated voltage for safety & efficiency.
- $\rightarrow$ Parallel connection ensures equal voltage to all appliances.