SUBJECT : SCIENCE (PHY)

CHAPTER-12:

ELECTRICITY

TOPIC-6:

HEATING EFFECT OF ELECTRIC CURRENT

&

JOULE'S LAW

OBJECTIVES:

Upon completion of the topic, you will be able to

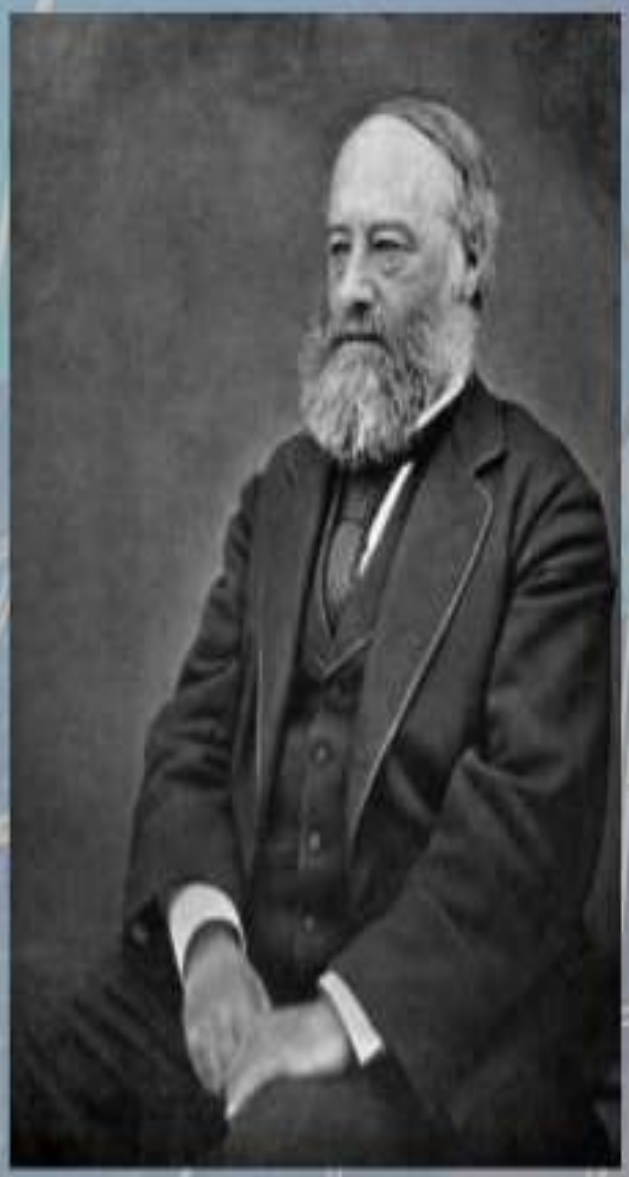
1. DEFINE HEATING EFFECT OF ELECTRIC CURRENT
2. EXPLAIN JOULE'S LAW OF HEATING
3. WRITE AND EXPLAIN APPLICATION OF JOULE'S LAW OF HEATING IN DAILY LIFE.
4. WRITE NAME OF APPLIANCES THAT WORK BASED ON HEATING EFFECT OF CURRENT
5. WRITE THE UNIT OF HEAT
6. WRITE THE NAME OF QUANTITIES ON WHICH HEAT PRODUCED IN A CONDUCTOR DEPEND.

Heating effect of electric current

- When electricity passes through a high resistance wire like a nichrome wire, the resistance wire becomes very hot and produces heat. This is called the heating effect of current.

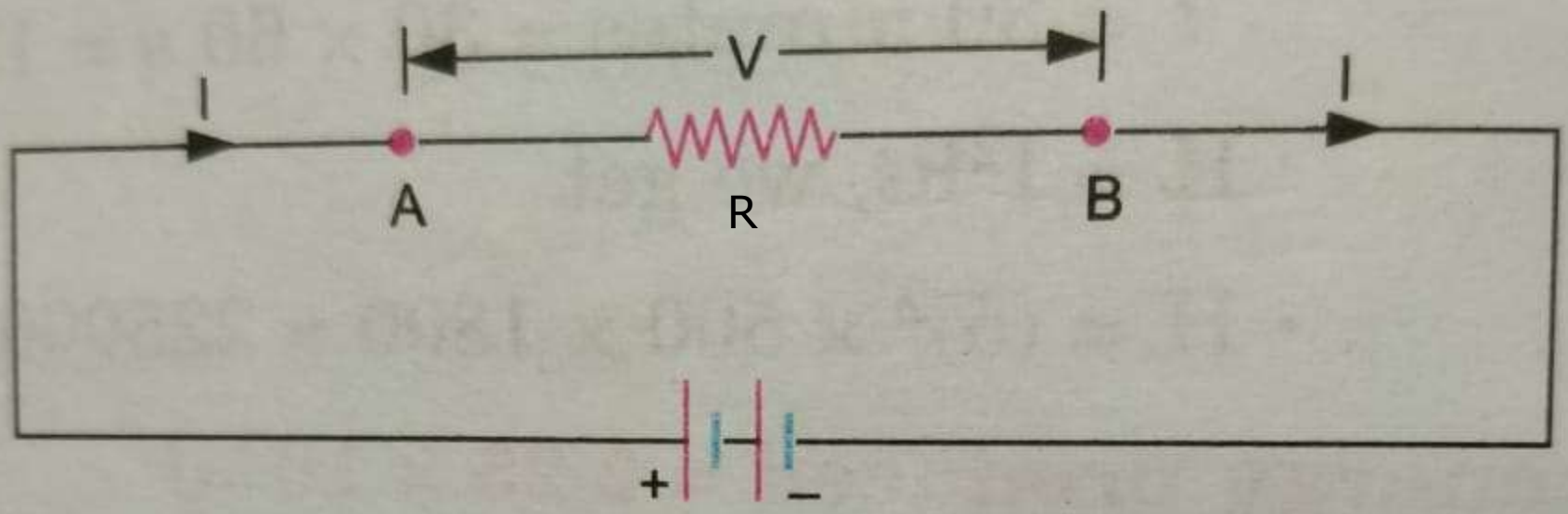
James Prescott Joule

James Prescott Joule (24 December 1818 – 11 October 1889) was an English physicist and brewer, born in Salford, Lancashire. Joule studied the nature of heat, and discovered its relationship to mechanical work. This led to the law of conservation of energy, and this led to the development of the first law of thermodynamics. The SI derived unit of energy, the joule, is named for James Joule. He worked with Lord Kelvin to develop the absolute scale of temperature. Joule also made observations of magnetostriction, and he found the relationship between the current through a resistor and the heat dissipated, which is now called Joule's first law.



HEAT PRODUCED DUE TO CURRENT IN A CONDUCTOR:

$$q = It$$



$$\text{Potential difference} = \frac{\text{Work}}{\text{charge}}$$

or $$V = \frac{W}{q} \quad \text{or} \quad W = V \times q \qquad ...(1)$$

If current I flows through the conductor for time t, then total charge flowing through the conductor is given by

$$q = It$$

Substitute this value of 'q' in eqn. (1), we get

$$W = V \times It \quad = \text{(Heat)} \qquad ...(2)$$

Using ohm's law

$V = IR$, where R is the resistance of the conductor

Equation (2) becomes: W = IR X It

$\therefore$

W= work = **Heat (H) = I^2Rt** (in joule)

JOULE'S LAW OF HEATING

For any conductor having resistance R, Heat produced due to electric current is:

$$H = I^2Rt$$

- This relation was experimentally verified by Joule and is known as Joule's law of heating. It states that **the heat developed in an electrical circuit due to the flow of current varies directly as**
- **(i) the square of the current** **($H \propto I^2$**
- **(ii) the resistance of the circuit and** **($H \propto R$)**
- **(iii) the time of flow.** **($H \propto t$)**

CAUSE OF PRODUCTION OF HEAT DUE TO CURRENT

Flow of electric charges constitute electric current in a conductor. On applying potential difference across the conductor, the free electrons move through it. But their motion is not smooth. They collide with the atoms or ions of the conductor and with each other. As a result of these collisions, kinetic energy of the free electrons is transferred to the atoms or ions of the conductor. Thus heat is produced when electric current flows through the metallic conductor.

PRACTICAL APPLICATION OF HEATING EFFECT OF CURRENT:

Many devices have been designed that work based on heating effect of electric current.

Examples: electric bulb, electric heater, electric iron, water heater electric fuses, electric lamp, welding etc

(1) Electric heater, electric iron, water heater etc work on the heating effect of current: when these appliances are connected to main supply of electricity, these become hot but the connecting wires remain cold. The element of electric heater is made up of nichrome. Nichrome has high value of resistivity and hence resistance. We know , heat produced is directly proportional to the resistance of the material through which current flows. Since, resistance of nichrome is high, so a large amount of heat is produced in the element of the electric heater. On the other hand, connecting wires are made of copper or aluminium. Since these metals have very small resistance, so a very small amount of heat is produced in the connecting wires.

PRACTICAL APPLICATION OF HEATING EFFECT OF CURRENT:

(2) Electric bulb glows when current passes through the bulb: Filament of an electric bulb is made of a thin wire of tungsten. The melting point of filament is high (about 3380 degree Celsius). Since resistance of thin filament is very high, so a large heat is produced as the electric current flows through the filament. Due to this large amount of heat produced, filament of the bulb becomes hot and emits light and heat.

(3) **Electric fuse in the electric circuit melts when large current flows in the circuit**: Electric fuse is wire made of a material whose melting point is very low. It is made up of metal or alloy of low melting point, for example aluminium, copper, lead etc. It is connected in series in circuit.when large amount of current flows through fuse wire, huge heat is produced and it gets melted and thus circuit is broken and flow of current stops.

Note : The Fuses used for domestic purposes are rated as: 1A,2A,3A,5A,10A,15A etc. It depends on to which appliance it is used.

QUESTIONS AND NUMERICALS:

Question 1:

Why does the cord of an electric heater not glow while the heating element does?

Answer 1:

The heating element of an electric heater is a resistor. According to Joule's law of heating, the amount of heat produced by it is proportional to its resistance.

$$H = I^2Rt$$

The resistance of the element of an electric heater is very high. As current flows through the heating element, it becomes too hot and glows red. On the other hand, the resistance of the cord is low. It does not become red when current flows through it.

Question 2:

Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential difference of 50 V.

Answer 2:

According to Joule's law of heating, the amount of heat produced is given by

$$H = VIt$$

Where, V = 50 V

t = 1 hr = 60 x 60 s

= 3600 s

I = Q/t = 96000/3600

= 80/3 A

H = VIt

= 50 x (80/3) x 3600

= 4800000 J

Question 3:

An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 30 s.

Answer 3:

According to Joule's law of heating, the amount of heat produced is given by

$$H = VIt$$

Where,

V = IR = 5A × 20 Ω = 100 V

I = 5 A

and t = 30 seconds So,

$$H = 100 \times 5 \times 30\ J$$

$$= 15000\ J = 1.5 \times 10^4\ J$$

Question 4:

An electric heater of resistance 8 Ω draws 15 A from the service mains in 2 hours. Calculate the rate at which heat is developed in the heater.

Answer 4:

Heat developed in the heater is given by $H = I^2Rt$

Where, I = 15 A, R = 8 Ω and time t = 2 hours The rate at which heat is developed is given by

$H = I^2Rt/t = I^2R = = (15)^2 \times 8 = 1800\ J/s$

QUESTION-5: Nichrome is used to make the element of electric heater. Why? [CBSE 2010]

Ans :

Nichrome is used to make element of electric heater because nichrome is an alloy which has high melting point and high resistances.

QUESTION-6: State the factors on which the heat produced in a current carrying conductor depends. Give one practical application of this effect. [Delhi 2014]

Ans :

We know that $H = VIt$ or $H = I^2Rt$

Heat produced in a current carrying conductor *H depends on:*

(a) I^2 (Square of the current in the circuit)

(b) R (Resistance of the conductor)

(c) t (Time for which current is passed in conductor)

This effect is applicable in electric heater

QUESTION-7:Elements of electric toasters and electric iron are made of an alloy rather than a pure metal. Give two reasons to justify the statement. [CBSE 2014]

Ans :

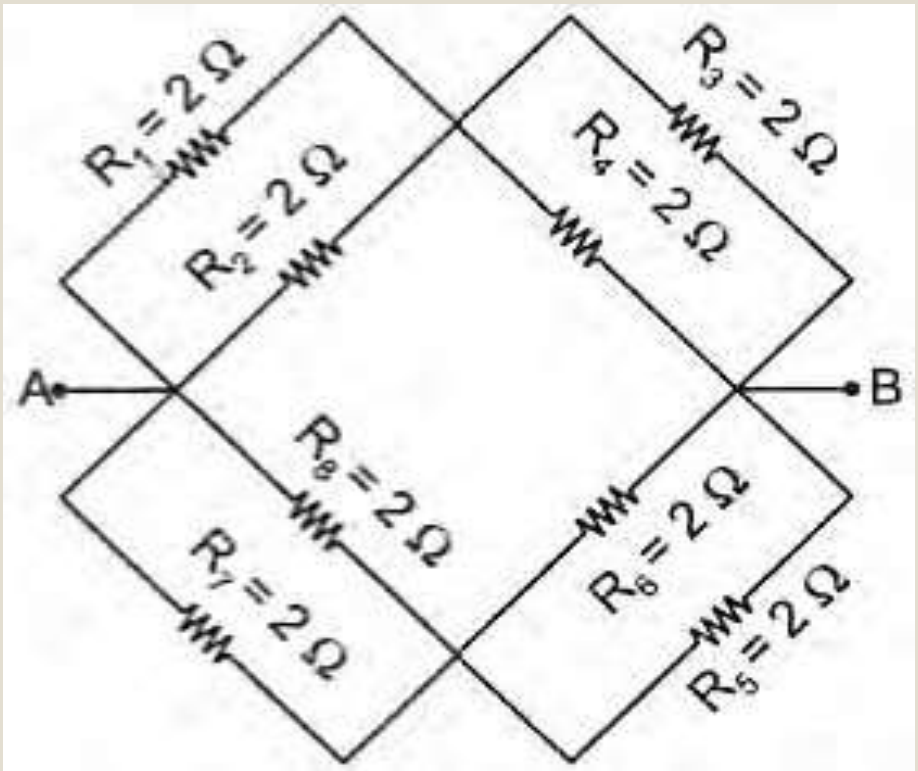
1. Alloys have higher resistivity than their constituents pure metals.
2. At high temperature alloys do not oxidise.

QUESTION-8: Write the units used to measure heat

ANS: (a) Joule(J) and
(b) Calorie (Cal)

HOME –WORK

1. QUESTION-1:
   Find the equivalent resistance across the two ends A and B of this circuit (from previous topic)



QUESTION-2: What do you understand by heating effect of electric current? Explain the cause of this effect.

QUESTION-3:

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

QUESTION-4: State Joule's law of heating.

QUESTION-4: Show that heat produced in a conductor of resistance R is $H = I^2Rt$, *where I is the current and t is the time.*