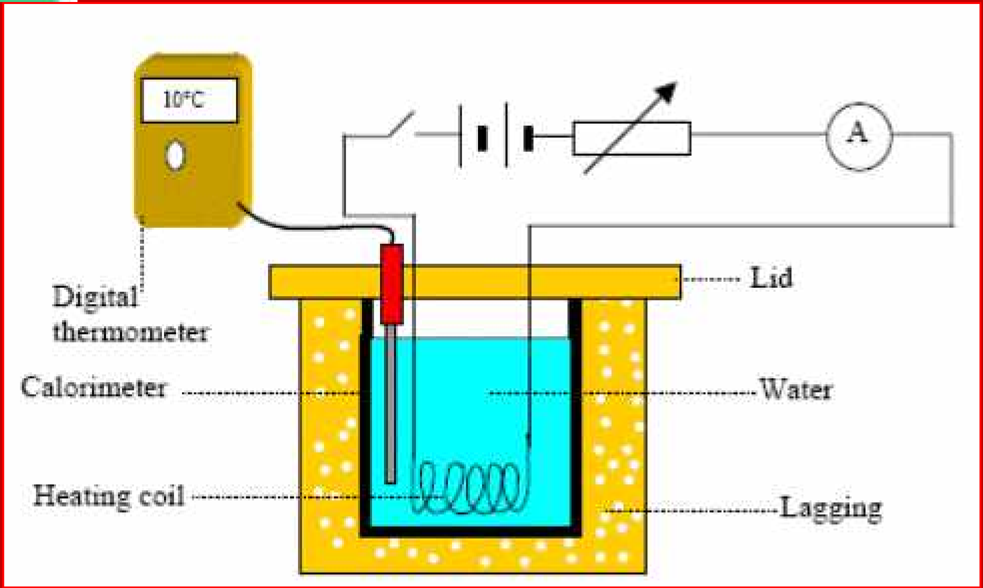
Chapter 8

HEATING EFFECT OF AN ELECTRIC CURRENT



$$Work\ done = VQ$$

$$since,\quad I = \frac{Q}{t}$$

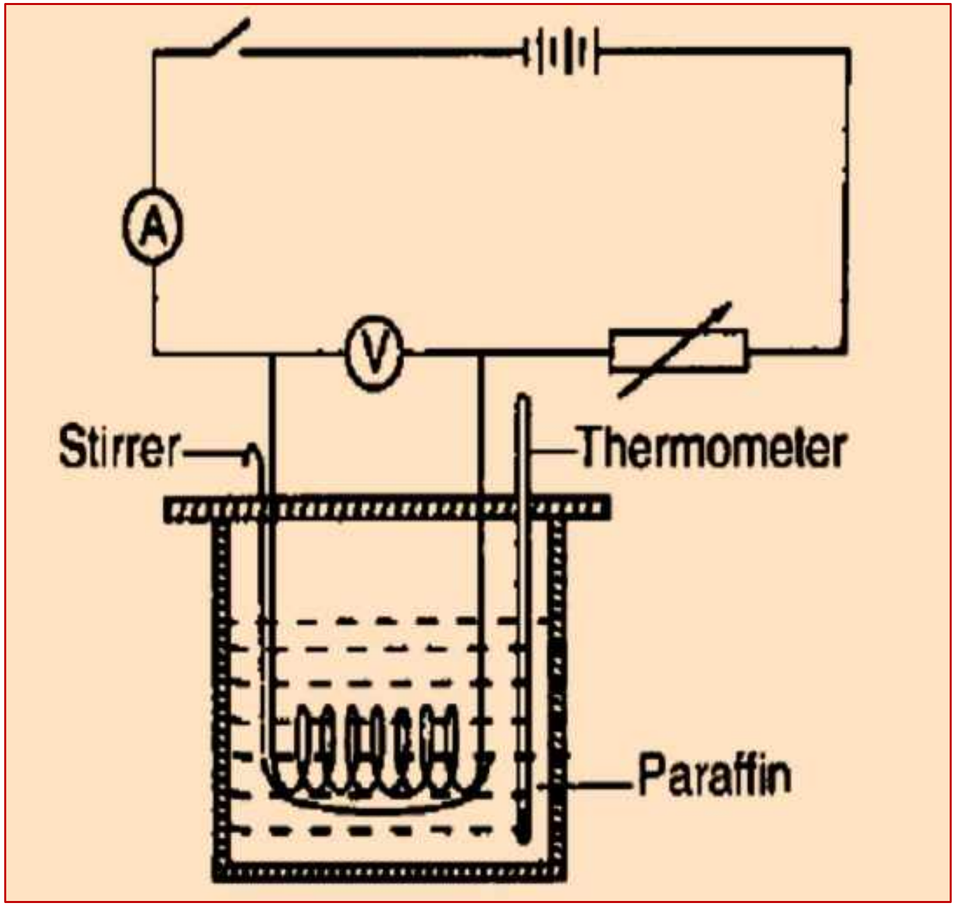
$$Work\ done = VIt$$

$$Work\ done = I^2Rt$$

$$Work\ done = \frac{V^2}{R}t$$

Demonstrating Heating Effect Of An Electric Current Using A Coil Of Wire

- The set-up below can be used to experimentally demonstrate heating effect of an electric current in the laboratory.



Precaution: the coil should be fully immersed in liquid but should not touch the bottom or walls of the beaker.

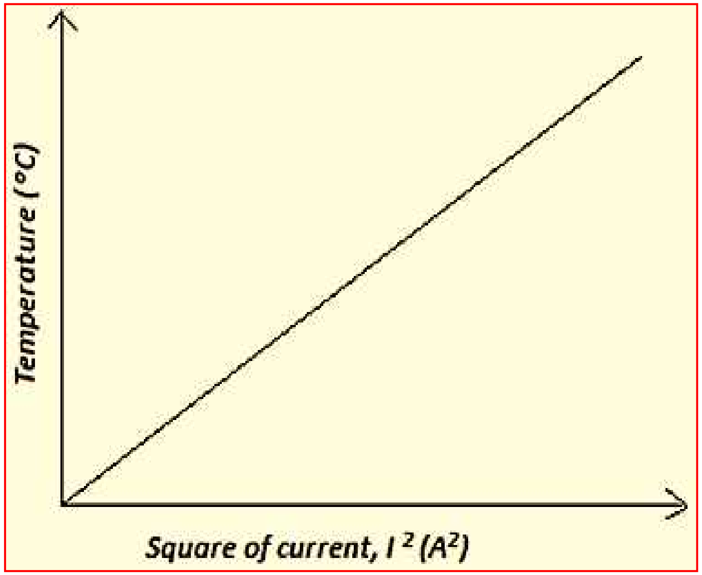
Observation: It is observed that the temperature of water increases with increase of resistance, current and time.

Explanation: Electrical energy is converted to heat energy resulting in a rise in temperature. The heat energy increases with resistance, current and time.

Factors Affecting Heating by Electric Current

1. Amount current passing through the conductor

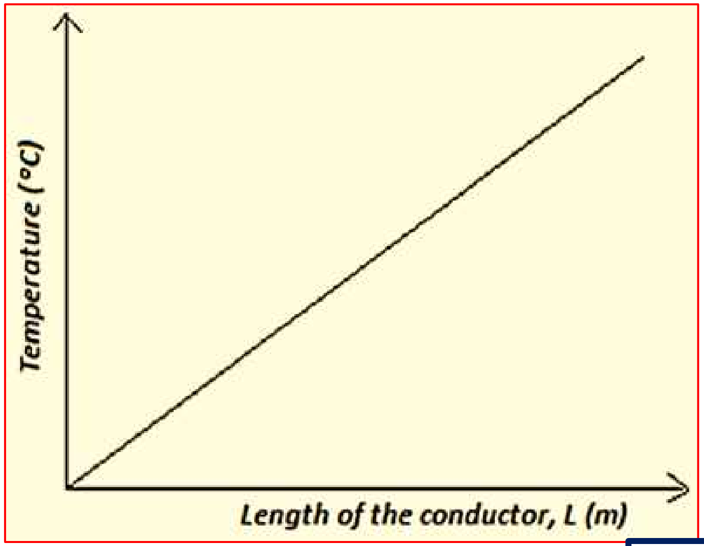
- The heat produced is directly proportional to the square of current through the conductor provided that same conductor is used for the same time. $i.e$ **$heat\ energy(E) \propto I^2$.**



2.Resistance of the conductor

Heat produced in a conductor carrying current is directly proportional to resistance of the conductor provided current and time are constant.

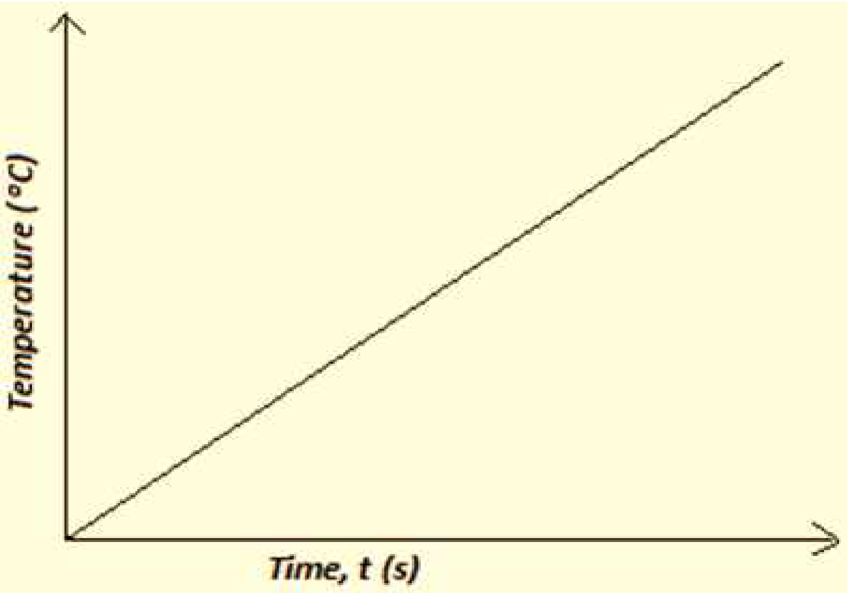
$heat\ energy\ (E) \propto R$.



Factors Affecting Heating by Electric Current

c) Time for which current flows through conductor

- Keeping current and resistance constant heat produced in a conductor is directly proportional to the time for which current flows. $\boldsymbol{Heat\ energy\ (E) \propto t.}$



Therefore

$$E = I^2Rt$$

Example 1

The potential difference across a lamp is 12 volts. How many juoles of electrical energy are changed to heat and light when:

(a) A change of 5 coulombs passes through it?

(b) A current of 2 A flows through the lamp for 10 seconds?

Solution

(a) W = QV

Energy changed to heat and light, W=5 x 12

= 60J

(b) W = Ivt

Energy changed to heat and light, W = 2 x 12 x 10

= 240 J

Example 2

An iron box has a resistance coil of 30Ω and takes a current of 10A. Calculate the heat in kJ developed in 1 minute.

Solution

R = 30Ω I = 10A, t = 60 a

$H = I^2Rt$

$= 10^2$ x 30 x 60

$= 18$ x 10^4

= 180 kJ

Electrical Energy, E

- *Consider a current* **I** *flowing through a conductor of resistance* **R** *for a time* **t**. *If a potential difference* **V** *drops across the ends of the conductor, then;*

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

$$\left(\boldsymbol{from\ definition\ of\ potential\ difference}\right)$$

$$E = W = VQ$$

$$\left(\boldsymbol{where\ \ W\ is\ the\ electrical\ work\ done\ in\ moving\ charge\ Q}\right)$$

- $\boldsymbol{This\ is\ electrical\ work\ done\ is\ converted\ to\ heat\ energy, E}$
- $\boldsymbol{but\ current, I = \frac{charge\ Q}{time, t};\qquad \Rightarrow Q = It}$
- $\boldsymbol{E = V(It);\quad \Rightarrow E = VIt}$
- $Since, \boldsymbol{V = IR}\ (\boldsymbol{from\ ohms\ law});\ electrical\ energy$
- $can\ also\ be\ expressed\ as;$

$$E = VIt = (IR)It;\qquad \Rightarrow E = I^2Rt$$

Electrical Power, P_E

- *Power is the rate of doing well*

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

$$= \frac{electrical\ energy}{time} = \frac{VIt}{t};$$

$$\Rightarrow Electrical\ power, P = VI$$

$$Since\ V = IR, electrical\ power\ can\ also\ be\ expressed\ as;$$

$$P = (IR)I$$

$$P = I^2R$$

$$Or\ from\ I = \frac{V}{R}; \quad P = V\left(\frac{V}{R}\right); P = \frac{V^2}{R}$$

Example 3

How much current does a bulb rated at 100 W and designed for a mains supply of 250V draw when operating normally?

Solution

P = VI

When the bulb is operating normally;

P= 100, V = 250

100 = I x 250

$I = \frac{100}{250}$

$= 0.40$ A

Example 4

What is the maximum number of 100 W bulbs which can be safely run from a 240 V source supplying a current of 5 A?

Solution

Let the maximum number of bulbs be n. maximum energy developed in the circuit per second equals total energy converted by the bulbs per second.

Thus, 240 x 5 = 100 n

So, $n = \frac{240 \times 5}{100}$

$= 12$ bulbs

Example 5

An electric light bulb has a filament of resistance 470Ω. The leads connecting the bulb to the 240 V mains have a total resistance of 10Ω. Find the power dissipated in the bulb and in the leads.

Solution

R = 470 + 10

= 480Ω

Therefore, $I = \frac{240}{480}$

= 0.5 A

For the bulb alone;

R = 470Ω and I = 0.5 A

Power dissipated = PR

$= (0.5)^2 \times 470$

= 117.5 W

For the leads alone, R = 10Ω and t = 0.5 A

Power dissipated $= (0.5)^2 \times 10$

= 2.5 W

Example 6

An electric iron of resistance 50Ω and an electric indicator of 6000Ω are connected in parallel to a 240 V mains supply. Find the dissipated in the electric iron and in the indicator.

Solution

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

For the iron alone;

V = 240 V, R = 6000Ω

$\text{Power} = \frac{240^2}{6000}$

= 9.6 W

Example 7

A hoist motor powered by a 240V mains supply requires a current of 30 A to lift a load of mass 3 tones at the rate of 5 m per minute. Calculate:

(a) The power input

(b) The power output

(c) The overall efficiency

Solution

(a)Power input = IV

= 20 x 240

= 7200 W

(b) Power output = force x velocity

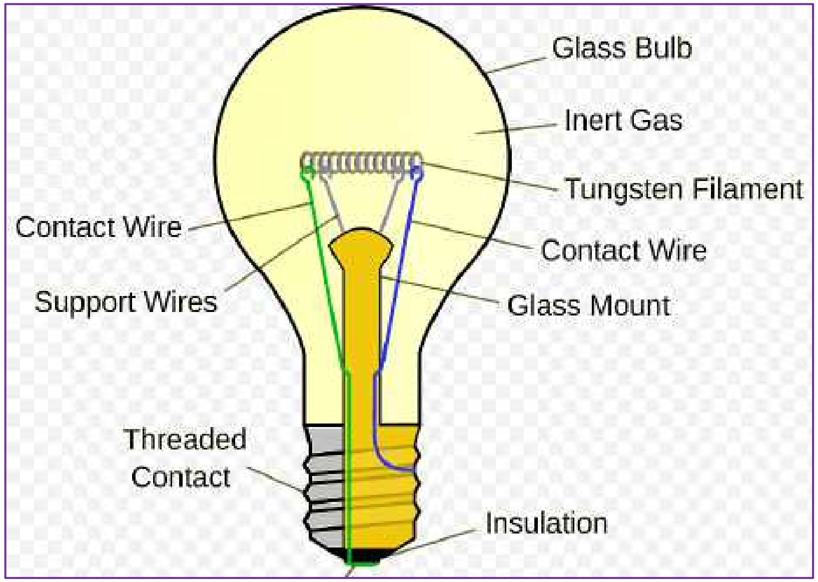
$= 3 \times 1000 \times 10 \times \frac{5}{60}$

(c) Efficiency $= \frac{2500}{7200} \times 100$

= 34.72 %

Applications of Heating by Electric Current

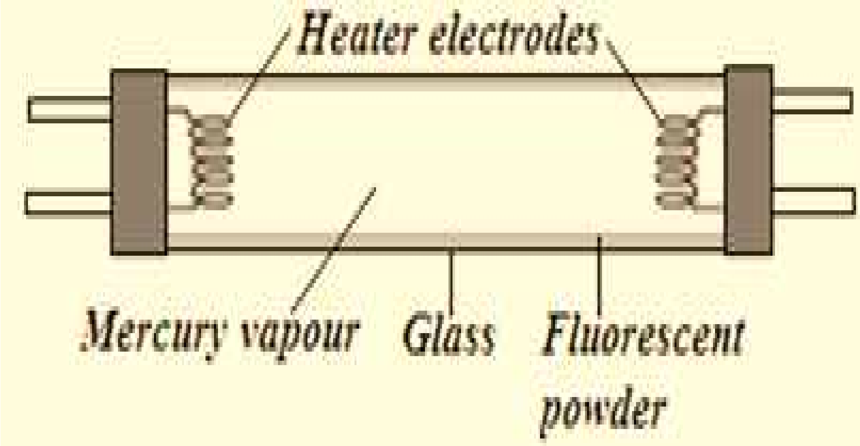
a) Filament lamps



- When current flows through the filament, it glows white hot and therefore produces light.
- The filament is made of ***tungsten*** metal due to its very high melting point (3400^{o}C).
- Air is removed to prevent oxidation of the filament
- The bulb is filled with ***inert gas like argon and nitrogen*** to reduce rate of evaporation of hot metals and increase life of bulb.

Applications of Heating by Electric Current

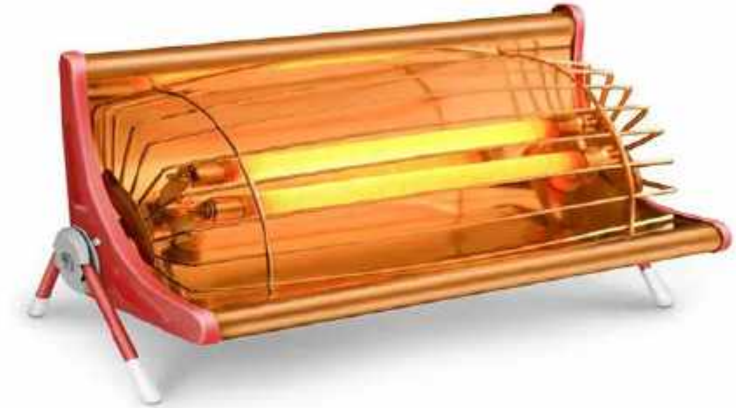
b) Fluorescent lamps



- They are efficient than filament lamps because they last much longer and have low running cost.
- It consists of the ***mercury vapor*** which produces ultraviolet radiation when the lamp is switched on. The radiation makes the ***powder*** on the inside of the tube produce ***visible light (fluoresce).***

Applications of Heating by Electric Current

Coil cooker



Room heater

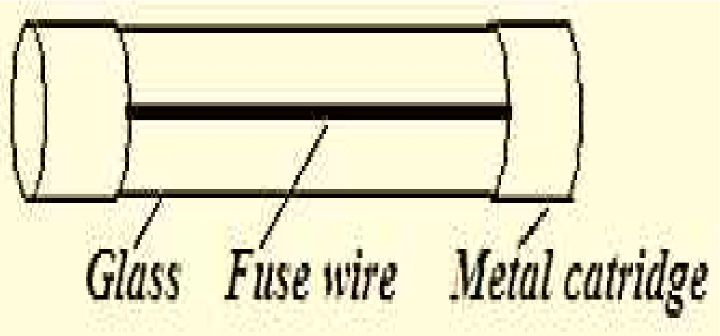
Iron box

Immersion heater

Applications of Heating by Electric Current

Fuse

- A fuse is a short length of wire of material with low ***melting point*** (tinned copper), which melts and breaks the circuit when current through it exceeds a certain value. This ***protects electrical appliances*** and prevents fire outbreaks.



1. State **three** factors which affect heating by an electric current.

2. State the energy changes which occur when one switches on a torch.

3. What is power as it relates to electrical energy?

4. Name **the** device which changes;

(i) Sound to electrical energy

(ii) Electrical energy to kinetic energy

4. An electric bulb rated **40W** is operating on **240V** mains. Determine the resistance of its filament

5. An Electric heater is rated **1000W, 240V.** Calculate the resistance of this element

6. An electric toy is rated **100W, 240V**. Calculate the resistance of the toy when operating normally.

7. Find the maximum number of 75W bulbs that can be connected to a 12A fuse on a 240V mains supply.

8. Two electric heaters A and B rated 1000 W and 2500 W respectively are connected in parallel across a 240 mains supply. Calculate the ratio R_A: R_B of their resistances.

9. A total charge of 360 coulombs is passed through an 80 ohms resistor in 30 seconds. Determine the amount of heat energy generated.

10. An electric bulb with a filament of resistance 480Ω is connected to a 240V mains supply. Determine the energy dissipated in 2 minutes.

11. A washing machine for use on 240V mains has a $^{1}/_{3}$h.p motor and a heating element rated 3Kw.(1h.p = 0.75kw) . **What** current does it take it take when in use.

12. Calculate the heat energy dissipated by a bulb rated **240W** working for **10** min

13. Fig represents part of electric cooker coil.

(i) Why is the material labeled X is coiled?

(ii) State the property of material X that makes it suitable for its use.