HEATING EFFECT OF ELECTRIC CUURENT Introduction

When current flows through a conductor, heat energy is generated in the conductor. The heating effect of an electric current depends on three factors:

- The resistance, R of the conductor. A higher resistance produces more heat.
- The time, t for which current flows. The longer the time the larger the amount of heat produced
- The amount of current, I. the higher the current the larger the amount of heat generated.

Hence the heating effect produced by an electric current, I through a conductor of resistance, R for a time, t is given by $H = I^2Rt$. This equation is called the Joule's equation of electrical heating.

Electrical energy and power

The work done in pushing a charge round an electrical circuit is given by w.d = VIt

So that power, P = w.d /t = VI

The electrical power consumed by an electrical appliance is given by $P = VI = I^2R = V^2/R$

Example

1. An electrical bulb is labeled 100W, 240V. Calculate:

a)The current through the filament when the bulb works normally
b)The resistance of the filament used in the bulb.

Solution

1. I = P/V = 100/240 = 0.4167A
2. R = P/I^2 = 100/ 0.4167^2 = 576.04Ω or R = V^2/P =240^2/100 = 576Ω

1. Find the energy dissipated in 5 minutes by an electric bulb with a filament of resistance of 500Ω connected to a 240V supply. { **ans. 34,560J**}

Solution

E = Pt = V2/R *t = (240^2 *5*60)/500 = 34,560J

1. A 2.5 kW immersion heater is used to heat water. Calculate:

1. The operating voltage of the heater if its resistance is 24Ω
2. The electrical energy converted to heat energy in 2 hours.

{**ans. 244.9488V, 1.8*10^7J**}

Solution

1. $P=VI=I^2R$

$I = (2500/24)^{1/2}$ =10.2062A

V=IR= 10.2062 * 24 = 244.9488V

1. E = VIt = Pt = 2500*2*60*60 = 1.8 * 10^7J

OR E= VIt = 244.9488 * 10.2062 * 2 * 60 * 60 = 1.8 * 10^7J

An electric bulb is labeled 100W, 240V. Calculate:
The current through the filament
The resistance of the filament used in the bulb.

Solution

P = VI I = P/V = 100/240 =0.4167A
From Ohm's law, V =IR R=V/I =240/0.4167 = 575.95Ω

Applications of heating effect of electric current

Most household electrical appliances convert electrical energy into heat by this means. These include filament lamps, electric heater, electric iron, electric kettle, etc.

In lighting appliances

1. Filament lamps- it is made of a tungsten wire enclosed in a glass bulb from which air has been removed. This is because air would oxidize the filament. The filament is heated up to a high temperature and becomes white hot. Tungsten is used due its high melting point; 3400^0 The bulb is filled with an inactive gas e.g. argon or nitrogen at low pressure which reduces evaporation of the tungsten wire. However, one disadvantage of the inert gas is that it causes convection currents which cool the filament. This problem is minimized by coiling the wire so that it occupies a smaller area which reduces heat loss through convection.
2. Fluorescent lamps- these lamps are more efficient compared to filament lamps and last much longer. They have mercury vapour in the glass tube which emits ultraviolet radiation when switched on. This radiation causes the powder in the tube to glow (fluoresce) i.e. emits visible light. Different powders produce different colours. Note that fluorescent lamps are expensive to install but their running cost is much less.

In electrical heating

1. Electric cookers- electric cookers turn red hot and the heat energy produced is absorbed by the cooking pot through conduction.
2. Electric heaters- radiant heaters turn red at about 900^0C and the radiation emitted is directed into the room by polished reflectors.
3. Electric kettles- the heating element is placed at the bottom of the kettle so that the liquid being heated covers it. The heat is then absorbed by

water and distributed throughout the whole liquid by convection.

4. Electric irons- when current flows through the heating element, the heat energy developed is conducted to the heavy metal base raising its temperature. This energy is then used to press clothes. The temperature of the electric iron can be controlled using a thermostat (a bimetallic strip).