Heating Effect – Joules Law

Heating effect of current:

Let V = P.D across the conductor

R = Resistance of the conductor

i =Current flowing through the conductor

If current flows for t sec then Q=i x t coulomb

We know that when a charge Q is taken through a potential difference V work done

W= Q x V = i x t x v ⟶ (1)

This work done by the charge is converted into heat

Heat energy produced H= i x t x v Joules

Thus when the current flows through the conductor heat is produced and is given by

H = ivt

H = iRvt

$H = i^2Rt$ ⟶ (2)

$\therefore H \propto i^2$ when R & t constant

$H \propto R$ when i & t constant

$H \propto t$ when i & R constant

The above three results are known as Joules law of heating effect of current which can be stated as follows:

First law: When current flows through a given conductor (R = constant) for a given time interval (t= constant) the heat produced is proportional to the square of current

$H \propto i^2$ when R & t constant

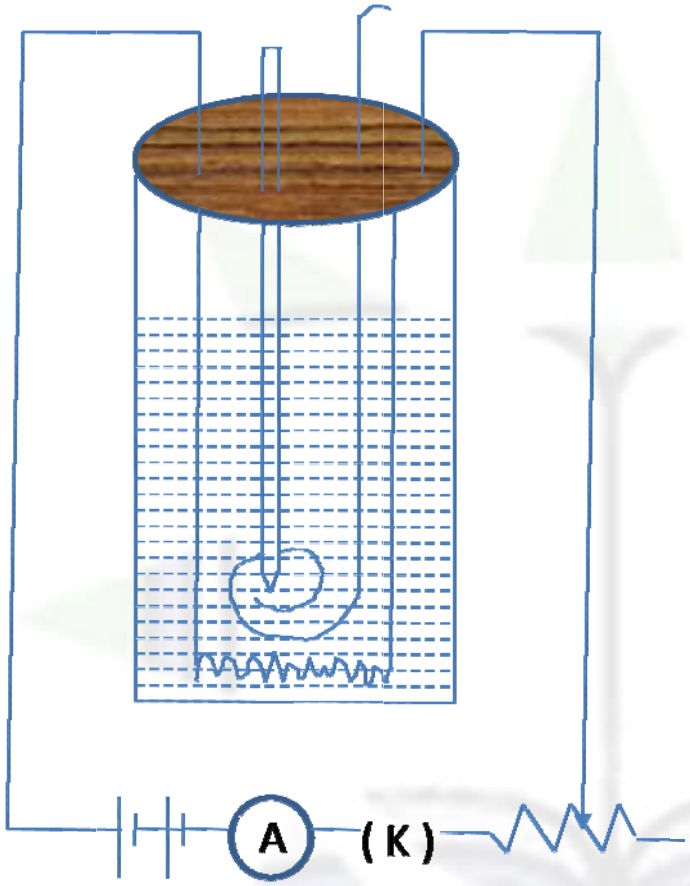
Second law: When a constant current flows for a given time interval (t = constant) the heat produced in the conductor is proportional to the resistance of the conductor when i & t are constant.

$H \propto R$ when i & t constant

Third law: When constant current flows through a given conductor the heat produced is proportional to the time of flow of current.

$H \propto t$ when i & R constant

Experimental Determination of Joules laws of heating effect of current



A copper calorimeter is taken and about 2/3rd of the calorimeter is filled with water and a thermometer is inserted into the water in the calorimeter. A resistance coil is immersed into the water in the calorimeter and the two ends of the coil are connected to two terminal screws at the top of the box in which the calorimeter is kept. A battery B an ammeter A, a key and a rheostat connected in series with the two screws.

Verification of first law:

Let m & S = mass and sp. Heat capacity of the calorimeter.

m' and S' = mass and sp. Heat of water in the calorimeter.

(1) By closing key K a constant current say i_1 recorded from the ammeter is passed and for a recorded time interval say t sec and the rise in temperature in the calorimeter is noted. Let θ_1 be the rise in temperature.

(2) With the rheostat current is changed to i_2 and again is passed for same time interval t sec and the rise in temperature θ_2 is noted.

The heat produced in the two experiments are H_1 & H_2 (say)

$$H_1 = \left(ms + m's'\right)\theta_1$$

$$H_2 = \left(ms + m's'\right)\theta_2$$

$$\frac{H_1}{H_2} = \frac{\theta_1}{\theta_2} \rightarrow (1)$$

From the recorded values it is found that

$$\frac{\theta_1}{\theta_2} = \frac{i_1^2}{i_2^2}$$

$$or\ H \propto i^2$$

Verification of second law: A constant current i is passed for the same time interval t sec by using two different coils immersed in the water in the calorimeter one by one and in each case the rise in temperature is recorded. Let R_1 and R_2 be the resistance and θ_1 & θ_2 be the corresponding rise in temperature. If H_1 and H_2 be the heat produced in the two cases then

$$H_1 = \left(ms + m's'\right)\theta_1$$

$$H_2 = \left(ms + m's'\right)\theta_2$$

$$\frac{H_1}{H_2} = \frac{\theta_1}{\theta_2} \rightarrow (1)$$

From the recorded values it is found that

$$\frac{R_1}{R_2} = \frac{\theta_1}{\theta_2} \rightarrow (2)$$

$or\ H \propto R$ when i & t are constant . Second law verified.

Verification of third law: A constant current is passed through the coil for two different time interval say t_1 and t_2 sec and the corresponding temperature θ_1 & θ_2 are recorded.

Let H_1 and H_2 be the heat produced then

$$H_1 = \left(ms + m's'\right)\theta_1$$
$$H_2 = \left(ms + m's'\right)\theta_2$$
$$\frac{H_1}{H_2} = \frac{\theta_1}{\theta_2} \rightarrow (1)$$

From the recorded values it is found that

$$\frac{H_1}{H_2} = \frac{t_1}{t_2} \rightarrow (2)$$

or $H \propto t$ when i & R are constant. Third law verified.