3.5 Thermal conductivity of good conductor Forbe's method

Metals are good conductors of both heat and electricity. To account for their heat conductor capacity, a quantity called "Thermal conductivity" is defined; higher the value of thermal conductivity more is the heat conduction. For example, copper is a very good conductor of heat followed by iron, aluminium etc. in decreasing order.

One of the oldest methods of determining the thermal conductivity of metals is being Forbes. In this method, a long rod of a metal with uniform cross section is heated at one of its ends. The entire length of the rod is left exposed to the surrounding air at the ambient room temperature.

As the rod gets heated up, it starts losing the acquired heat from its exposed surface to the surroundings. After a certain period a steady state is reached in, which

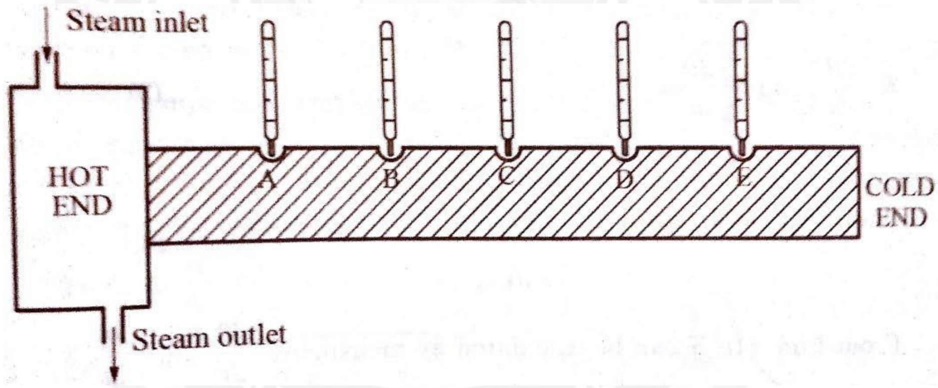

Fig 3.5 .1:Forbe's method

the entire heat supplied to the rod is lost to the surroundings. Let us consider cross section of the rod along its length at a distance 'x' from the heated end, as shown in figure.

Theory

Before steady state is reached, the amount of heat conducted through a particular point say B, per second can be written as,

$$Q_1 = KA\left(\frac{d\theta}{dx}\right)_B \text{---------------}(1)$$

Here K is the thermal conductivity of the material

A is the area of cross section of the material

$(\frac{d\theta}{dx})_B$ is the change in temperature per unit length of the rod at B

The total heat lost from the point B to E is, $Q_2 = \rho SA\int_B^E \frac{d\theta}{dt}dx$

S – Specific heat capacity,

ρ – Density

In a steady state condition, $Q_1 = Q_2$

$$K(\frac{d\theta}{dx})_B = \rho SA\int_B^E \frac{d\theta}{dt}dx$$

Thermal conductivity

$$K = \frac{\rho SA \int_B^E \frac{d\theta}{dt}dx}{K(\frac{d\theta}{dx})_B}$$

From equation (4), K can be calculated by measuring $\frac{d\theta}{dx}$ and $\frac{d\theta}{dt}$

Procedure:

- In the experimental set up, heater is switched on and the rod is allowed to rise to steady state temperature. At this state the temperature at points A, B, C, D etc. remains constant without any variation with time.
- The temperature at the points A, B, C, etc. are noted and tabulated. The distance of the points A, B, C, etc. from the hot end is also noted. A graph is plotted by taking distance alone *x*-axis and temperature along *y*-axis as shown in figure

To find $(\frac{d\theta}{dx})_B$:

Position	Distance from the hot end	Temperature θ (^{0}C)

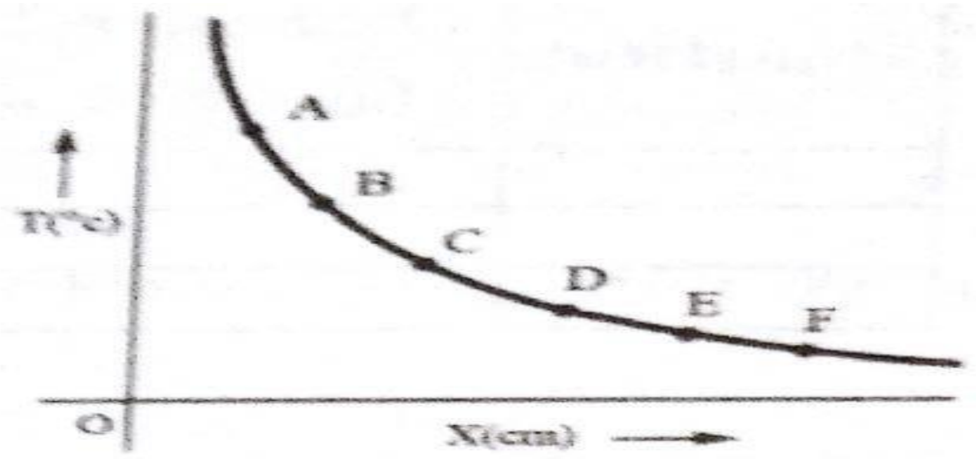

Fig 3.5.2 -To find $(\frac{d\theta}{dx})$

- Find the slope of the curve at any two points. From the slope $(\frac{d\theta}{dx})_B$ has been found.
- Heat the sample rod using a heater or boiling water bath for a sufficient time to reach a steady state. Take out the sample rod, hang it using a string and stand. Insert the thermometer into the groove as shown in figure.

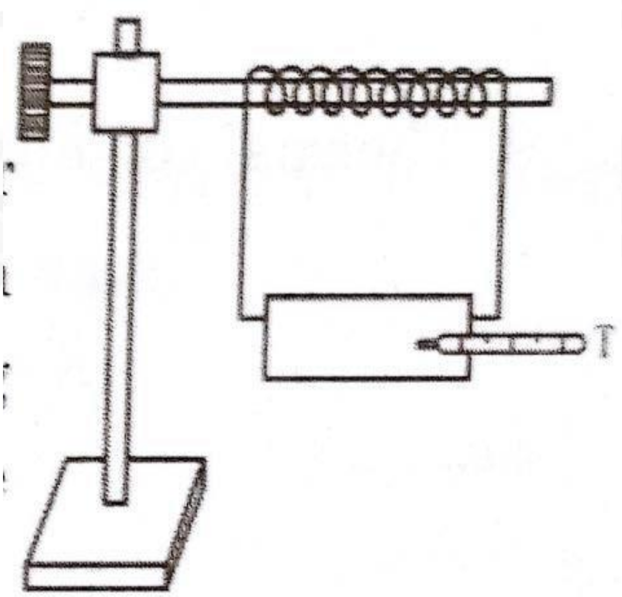

Fig 3.5.3- Set up to find temperature vs time

- Measure the temperature as a function of time at regular interval, using a stopwatch and the thermometer. Tabulate them as suggested in below table. A graph is plotted by taking time along *x*-axis and temperature along *y*-axis as shown in figure.

- To find $\frac{d\theta}{dt}$

Sl.No	Time	Temperature θ (^{0}C)

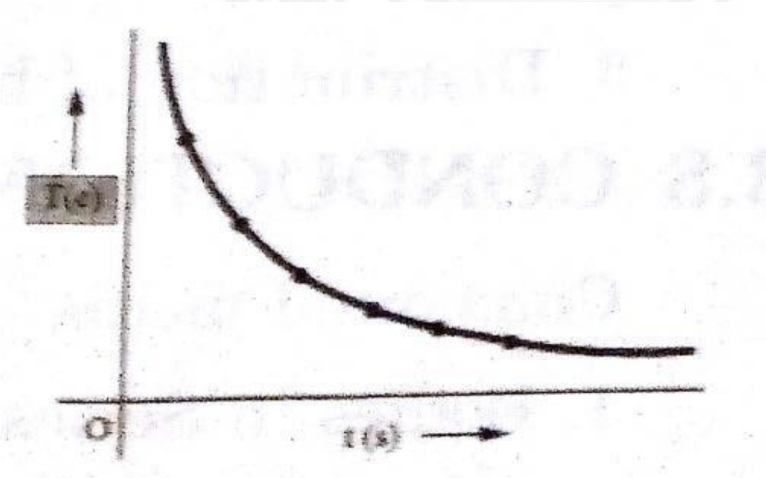

Fig 3.5.4-Graph to find $\frac{d\theta}{dt}$

- Find the slopes $\frac{d\theta}{dt}$ at the points A, B, C, D etc. from the figure.
- Now a graph is plotted by taking $\frac{d\theta}{dt}$ along *y*-axis and distance along *x*-axis as

shown in figure.

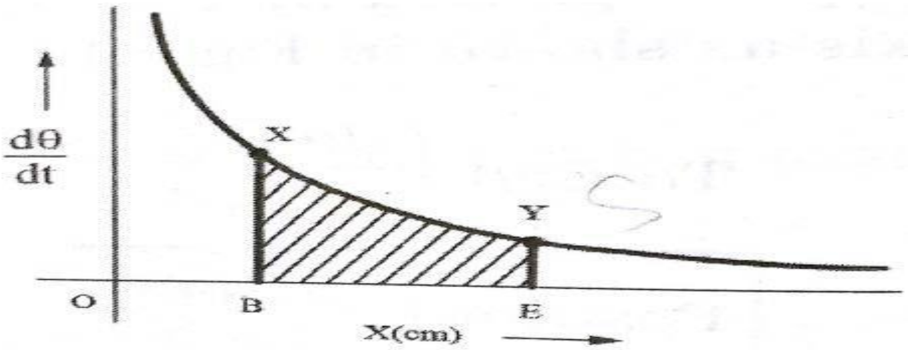

Fig 3.5.4-Graph to find Area ie $\frac{d\theta}{dt}$ vs x

- Mark two points x and y on the graph corresponding to the position B and E. Determine the area under the curve X, Y. BXYE in figure.

Area of $BXYE$ = $\int_B^E \frac{d\theta}{dt}dx$ ------------------------(5)

Thermal conductivity K can be calculated using equation (4) and (5).

K = $\frac{\rho S \text{Area of BXYE}}{(\frac{d\theta}{dx})_B}$ ---------------------(6)

Note that instead of B and E, any two pair of points can be taken and accordingly the equation (6) can be modified.

Drawbacks:

1. Time consumption is long to complete the experiment.
2. It is bore to draw three graphs.
3. Distribution of heat is not the same all over the rod.