Lee’s Disc Method

Object. To determine the thermal conductivity of a non-conducting material by the Lee's disc method.

Apparatus Required. Lee's apparatus, steam boiler, two thermometers, vernier callipers, heater, stop-watch, screw gauge, physical balance and weight box.

Description of the apparatus. Lee's apparatus is shown in Fig. 1. It consists of a metallic ring R attached to a heavy vertical stand. A circular solid disc C of brass (or copper) is suspended from the ring R. A steam chamber S is kept on the disc C. The steam chamber is provided with another solid disc B at its base. The experimental non-conducting disc G is kept in between the discs B and C. The discs B and C have openings to insert thermometers T_1, and T_2 in them.

Theory. For the experiment, steam is passed in the steam chamber S. In the steady state, the amount of heat passing per second from the disc B to the disc C through the non-conducting disc G, is lost per second by radiation from the lower surface and curved surface of the disc C. Let $A=\pi r^2$ if r is the radius of disc) be the

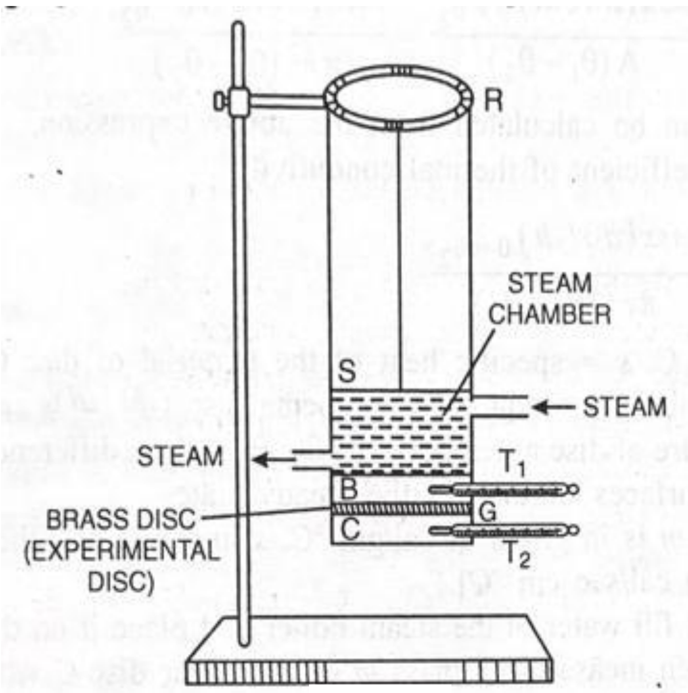

Fig. 1

area of plane surface of experimental disc and x be its thickness. If in steady state, the temperature recorded by the thermometers T_1, and T_2 be θ_1 and θ_2 respectively, then heat conducted per second through the non-conducting disc is

$$Q = \frac{KA(\theta_1 - \theta_2)}{x} \quad \dots (1)$$

where K is the coefficient of thermal conductivity of the material of nonconducting disc.

Now if the rate of fall of temperature of disc C at temperature θ_2 is $(d\theta/dt)_{\theta=\theta2}$ and the mass of disc C is m, specific heat of its material is s, then the heat lost per second by radiation from the disc C is

$$Q' = ms\left(\frac{d\theta}{dt}\right)_{\theta=\theta_2} \quad \dots (2)$$

In the steady state, if the heat radiated by the disc G is neglected then **Q = Q'**

then,

$$\frac{KA(\theta_1 - \theta_2)}{x} = ms\left(\frac{d\theta}{dt}\right)_{\theta=\theta_2}$$

$$K = \frac{msx(d\theta/dt)_{\theta=\theta_2}}{A(\theta_1 - \theta_2)} = \frac{msx(d\theta/dt)_{\theta=\theta_2}}{\pi r^2(\theta_1 - \theta_2)} \quad \dots (3)$$

The value of K can be calculated from the above expression.

Formula used. Coefficient of thermal conductivity

$$K = \frac{msx\left(d\theta/dt\right)_{\theta=\theta_2}}{\pi r^2 (\theta_1 - \theta_2)}$$

… (4)

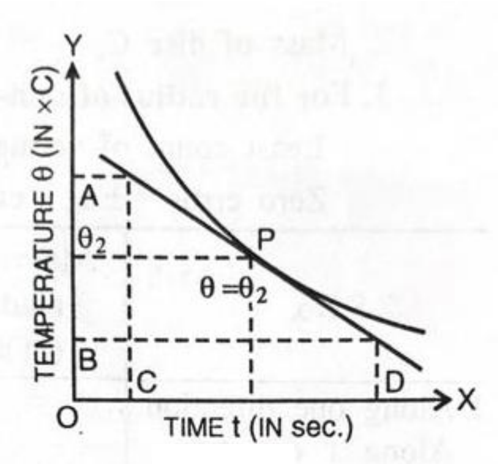

Fig. 2

where,

m = mass of disc C,

s = specific heat of the material of disc C,

x = thickness of experimental disc,

r = radius of experimental disc,

$(d\theta/dt)_{\theta=\theta_2}$ = rate of fall of temperature of disc at temperature θ,
$\theta_1 - \theta_2$ = difference in temperatures of the surfaces of disc in the steady state.

[Remember that if *m* is in gm, *s* in cal/gm °C, *x* and *r* in cm, then the value of K will be in cal/sec cm °C].

Procedure. (Not to be written in copy)

1. First fill water in the steam boiler and place it on the burner to form steam. Then measure the mass *m* of the lower disc C with the help of physical balance.

2. Note least count and zero error of vernier callipers. Measure the diameter of the experimental non-conducting disc G at various places and at each place in two mutually perpendicular directions, using a vernier callipers. Then take its mean and divide by 2 to find its mean radius *r*.

3. Note least count and zero error of screw gauge. Measure the thickness of the experimental non-conducting disc G at several places with the help of screw gauge.

4. Now place the experimental disc G in between the discs B and C. Insert the thermometers T_1 and T_2 in the openings provided in discs B and C.

5. Allow steam to pass in the steam chamber from the boiler. Wait for 4-5 minutes and then note the readings of thermometers T_1 and T_2 after each 2 minutes. When the readings θ_1 and θ_2 become constant, note these readings.

6. Stop passing steam in the steam chamber and remove the disc C from the apparatus. Now heat the disc C by keeping it on a heater till its temperature rises to 10°C above θ_2. Suspend the disc C alone from the ring R and allow it to cool. Now, record its cooling by noting the time (in seconds) for the fall in temperature by 1°C, till its temperature falls to 10°C below θ_2. Note the specific heat of material of disc C form the standard table.

7. Then plot a graph X-axis and temperature θ on Y-axis as shown in Fig. 2. Draw tangent to the curve at point P corresponding to the temperature θ_2 and find its slope which gives the value of $(d\theta/dt)_{\theta=\theta_2}$.

Observations.

1. Specific heat of material of disc C, *s* = ……....... cal/gm °C (From standard tables)

2. Mass of disc C, m =……….. gm

3. **For the radius of non-conducting disc G**

Least count of vernier callipers = ... cm

Zero error = ± ...... cm

S. No.	Main Scale Reading (cm)	Vernier Scale Reading (cm)	Total reading = Observed diameter (cm)
1. Along one direction			
Along ⊥ direction			
2 Along one direction			
Along ⊥ direction			
3. Along one direction			
Along ⊥ direction			

Mean observed diameter = ...cm

Mean diameter d of disc G = Observed diameter - Zero error (with sign)

=........... cm

Radius of disc G, $r = \frac{\text{Mean diameter } d}{2}$ = ... cm

4. **For the thickness of disc G**

Least count of screw gauge = ... cm

Zero error = ± ...... cm

S. No.	Main Scale Reading (cm)	Circular Scale Reading (cm)	Total reading (cm)
1.			
2.			
3.			

Mean observed thickness = ...cm

Actual thickness of disc G, x = observed thickness - zero error (with sign)

=.......cm

5. Least count of thermometer = ...°C

6. Steady temperature of thermometer T_1 (i.e., steady temperature of disc B) θ_1=..........ºC

7. Steady temperature of thermometer T_2 (i.e., steady temperature of disc C) θ_2=……....ºC

8. **For the cooling curve of disc C**

Least count of stopwatch = ... sec

S.No.	Time *t* (sec)	Temperature of disc C (ºC)	S.No.	Time *t* (sec)	Temperature of disc C (ºC)
1.			11.		
2.			12.		
3.			13.		
4.			14.		

5.			15.		
6.			16.		
7.			17.		
8.			18.		
9.			19.		
10.			20.		

9. From the above observation table, a graph is plotted for temperature θ on Y-axis and time *t* on X-axis. From this graph (Fig. 2), the slope of the tangent drawn on curve at $\theta = \theta_2$, is

$(d\theta/dt)_{\theta=\theta 2} = \frac{AB}{CD}$ **= .....°C/sec.**

Calculations. Substituting the values of all the quantities on the right-hand side of the expression

$$K = \frac{msx(d\theta/dt)_{\theta=\theta_2}}{\pi r^2(\theta_1-\theta_2)}$$

the value of K can be calculated.

K = ... cal/sec cm °C.

Result. The coefficient of thermal conductivity of the given non-conducting material (......................) = ... cal cm^{-1} sec^{-1} $°C^{-1}$

Standard value = ... cal cm^{-1} sec^{-1} $°C^{-1}$ (From standard tables)

Precautions.

(i) The readings of thermometers should be noted after attaining the steady state.

(ii) The thermometers must be sensitive.

(iii) The experimental non-conducting disc must be thin so that heat loss by radiation from its curved surface may be negligible.

(iv) The thickness and diameter of the experimental non-conducting disc must be measured before placing it in the apparatus (i.e., before heating it).

(v) Before the experiment, it must be checked that there is sufficient water in the boiler for generation of steam.

Viva-Voce

Q. What are the various modes of transfer of heat?

Ans. (i) conduction, (ii) convection, and (iii) radiation.

Q. How is heat transferred particularly in solids?

Ans. By conduction.

Q. What do you understand by the terms 'thermal conductivity' and 'coefficient of thermal conductivity'?

Ans. Thermal conductivity is the property of a substance due to which heat is transferred through that substance by conduction. The coefficient of thermal conductivity of a material is the amount of heat passing per second through the rod of that material of length 1 cm and area of cross-section 1 cm^2 when the difference in temperatures at its ends is 1°C.

Q. What is the unit of coefficient of thermal conductivity?

Ans. cal cm^{-1} sec^{-1}°C^{-1}or joule $metre^{-1}$ $second^{-1}$ °C^{-1}.

Q. Which substance is best conductor of heat?

Ans. Silver.

Q. What are the values of K for an ideal conductor and an ideal insulator?

Ans. K = infinite for an ideal conductor and K = zero for an ideal insulator.

Q. Which of the following is the best conductor of heat? Copper, Silver, Aluminium, Brass.

Ans. Silver.

Q. Which of the following is the best insulator of heat? Wood, Glass, Mercury, Air.

Ans. Air.

Q. Name a substance which is good conductor of heat but an insulator of electricity?

Ans. Mica.

Q. On what factors does the rate of rise in temperature of disc in the variable state depend?

Ans. On (i) thermal conductivity, (ii) specific heat, and (iii) density of the material of disc.

Q. Why do the readings of the two thermometers not change with time in the steady state?

Ans. Because in the steady state, the rate of flow of heat from the B to the disc C through the non-conducting disc is equal to the rate at which heat is radiated from the lower surface and curved surface of the disc C.

Q. Do the two thermometers have the same readings, in the steady state?

Ans. No. The two thermometers do not have the same readings, but there is a temperature gradient between the plane surfaces of the experimental disc.

Q. What do you mean by the term temperature gradient?

Ans. The rate of fall of temperature with distance in direction of flow of heat is called the temperature gradient.

Q. On what factors does the amount of heat conducted through the disc in the steady state depends?

Ans. In the steady state, the amount of heat Q conducted through the disc is (i) directly proportional to the area of cross-section A of the disc, (ii) inversely proportional to the thickness x of disc, (iii) directly proportional to the temperature difference $\theta_1 - \theta_2$ across the disc, and (iv) directly proportional to time t.

Q. You are given two circular discs of same thickness and same radius with the same temperature difference across them. But one disc is of glass and the other disc is of rubber. Will the rate of heat conducted by them be equal?

Ans. No. The rate of conduction of heat through the glass disc will be more than that through the rubber disc.

Q. Why do you take the experimental substance in the form of circular disc in this experiment?

Ans. So that the thickness of disc is small, but its area of cross-section is large (otherwise the rate of conduction of heat through the non-conducting material will be very low).

Q. Can you determine the heat conductivity of a good conductor this method?

Ans. No. The reason is that if we take the disc of a good conductor, the rate of conduction of heat through it will be very high and so the temperatures across it will be nearly equal.

Q. Can you determine the conductivity of a liquid by this method?

Ans. Yes. For this, the experimental liquid is taken in a hollow thin-walled disc of a non-conducting material and this disc is then placed between the discs B and C.

Q. Why do you note the temperature recorded by the thermometers when the steady state is attained?

Ans. Because while obtaining the expression used in this experiment, it has been assumed that the experimental disc is in the steady state.

Q. How do you check that the steady state has been achieved?

Ans. Steady state is achieved when the temperatures recorded by the two thermometers do not change with time.

Q. How is the coefficient of thermal conductivity of a substance affected by the change in temperature?

Ans. Generally the coefficient of thermal conductivity of a substance decreases with the increase in its temperature.