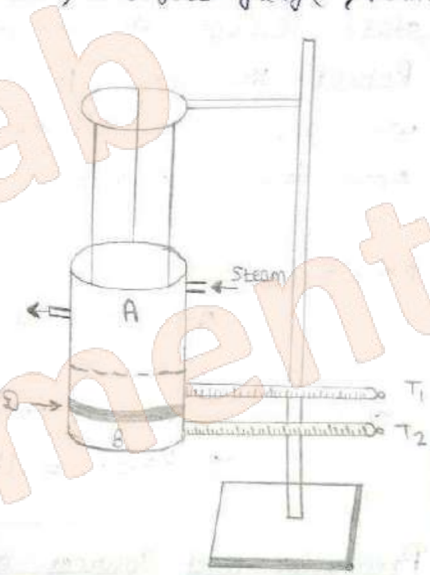
To Determine the Coefficient of thermal conductivity of a bad conductor by Lee's and Charlton's Method

Aim :-
To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's method.

Apparatus :-
Lee and Charlton's apparatus, Circular disc (of the same diameter as the disc in apparatus) of bad conductor, 2 thermometers, steam generators, stand and threads, a stop-watch, a screw-guage, vernier calliper and a balance.

Diagram :-



Observation :-
Specific heat of the material of the slab B, $S = 0.089$ cal gm^{-1} $°C^{-1}$

Mass of slab B, $m = 715$ gm

Vernier constant $= 0.01$ cm.

Diameter of the disc D =

MSR	VSR	D (MSR + VSR × LC)
11.5	7	11.57

$D = 11.57$ cm

Radius, $r = 5.785$ cm

Circular area of the disc D, $A = \pi r^2 = 105.083947$ cm^2

$A = 105.084$ cm^2

Least Count of Screw Guage $= \frac{0.5}{100}$ mm $= 0.005$ mm $= 0.0005$ cm

Least Count of Vernier Calliper $\Rightarrow$ 10 VSD = 9 MSD   1 VSD $= \frac{9}{10}$ MSD

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Lee and charlton's apparatus, circular disc (of the same diameter as the disc in apparatus) of a bad conductor, two thermometers, steam generators, stand and threads, a stop-watch, a screw-guage, vernier calliper, a balance.

Theory :-

When steam is passed through the hollow chamber A, it flows to the metallic slab B through the bad conductor D. T_2 (temperature of B) due to this flow rises.
When the heat gained per second by slab B becomes equal to the heat lost by it per second, steady state is reached and the temp. in T_1 and T_2 remain constant after this. Thus, at stead state Heat gained per sec = Heat lost per sec.
If K is the coefficient of thermal conductivity of the material of bad conductor, d its thickness, A its area of cross section (circular area) and T_1 and T_2 the temp. on its two sides, the heat gained by the slab B per sec is

$$Q = \frac{KA(T_1 - T_2)}{d}$$

If m is mass of slab B, s is specific heat of its material, T_2 its temp. then the heat lost by it per sec is

$$Q = \dot{m}s\left(\frac{dT}{dt}\right)_{T_2}$$

where $\left(\frac{dT}{dt}\right)_{T_2}$ is the rate of fall of the temp. of the slab B at

$\left(\frac{MSD - VSD}{MSD}\right) \times$ smallest that you can measured on main scale

$\left(\frac{MSD - \frac{9}{10} MSD}{MSD}\right) \times 0.1 = 0.01\ cm$

Thickness of disc D,

MSR	CSR	d
1	67	1.335
1	71	1.355
1	66	1.33

Mean thickness, $d = \frac{1.335 + 1.355 + 1.33}{3} = 1.34\ mm$

Error in Screw Guage $= -10 \times 0.005\ mm = -0.05\ mm$

$d = 1.34 - (-0.05) = 1.39\ mm$

$d = 0.139\ cm$

Steady State Temp., $T_1 = 94.3°C$

$T_2 = 74°C$

$T_1 - T_2 = 20.3°C$

Least count of thermometer $= 0.1°C$

For cooling curve of metal slab B

Sr. No.	Time t (sec)	Temp. of B (°C)
1.	30	81.5
2.	60	80
3.	90	78.5
4.	120	77
5.	150	76
6.	180	75
7.	210	74
8.	240	73.3
9.	270	72.4
10.	300	71.6
11.	330	71.8
12	360	70

temp. T_2.

So, at steady state,

$$\frac{KA(T_1 - T_2)}{d} = m_s \left(\frac{dT}{dt}\right)_{T_2}$$

$$\boxed{K = \frac{m_s d}{A(T_1 - T_2)} \left(\frac{dT}{dt}\right)_{T_2}}$$

Procedure :-

(i) Weigh the slab B and determine its mass m_s.

(ii) Measure the diameter of the experimental disc D with the help of vernier callipers at a number of places. Find the mean diameter.

(iii) Measure its thickness d with the help of screw guage at a number of places and determine the mean thickness d.

(iv) Arrange the apparatus as shown in Fig with experimental disc D sandwiched between A and B. Pass steam through A and after about half an hour, record the temp. T_1 and T_2 at regular interval of 2 minutes. When T_1 and T_2 become constant, the steady state is reached. Record T_1 and T_2 for the steady state.

(v) To find out $\left(\frac{dT}{dt}\right)_{T_2}$, heat the slab B alone separately until its temp. is about 10°C above the steady state Temperature T_2. Suspend B by means of threads with the experimental disc D on the top of it, allow it to cool. (Disc D is kept on it so as to keep the exposed area of B same (S+A) as before. If it is not covered from top, the exposed area would be (S+2A) whereas earlier it was (S+A). This would create error in the determination of coefficient of thermal conductivity).

Calculation :-

$$K = \frac{msd}{A(T_1 - T_2)} \left(\frac{dT}{dt}\right)_{T_2}$$

From Graph: $\left(\frac{dT}{dt}\right)_{T_2} = \frac{AB}{BC} = \frac{5}{150} = 0.0333 \ ^{\circ}C \ s^{-1}$

$$K = \frac{715 \times 0.089 \times 0.139 \times 0.0333}{105.084 \times 20.3}$$

$K = 1.38 \times 10^{-4} \ Cal \ s^{-1} \ cm^{-1} \ ^{\circ}C^{-1}$

As $1 \ cal \ s^{-1} \ cm^{-1} \ ^{\circ}C^{-1} = 420 \ J \ s^{-1} \ m^{-1} \ K^{-1}$

$$\boxed{K = 579.6 \times 10^{-4} \ J \ s^{-1} \ m^{-1} \ K^{-1}}$$

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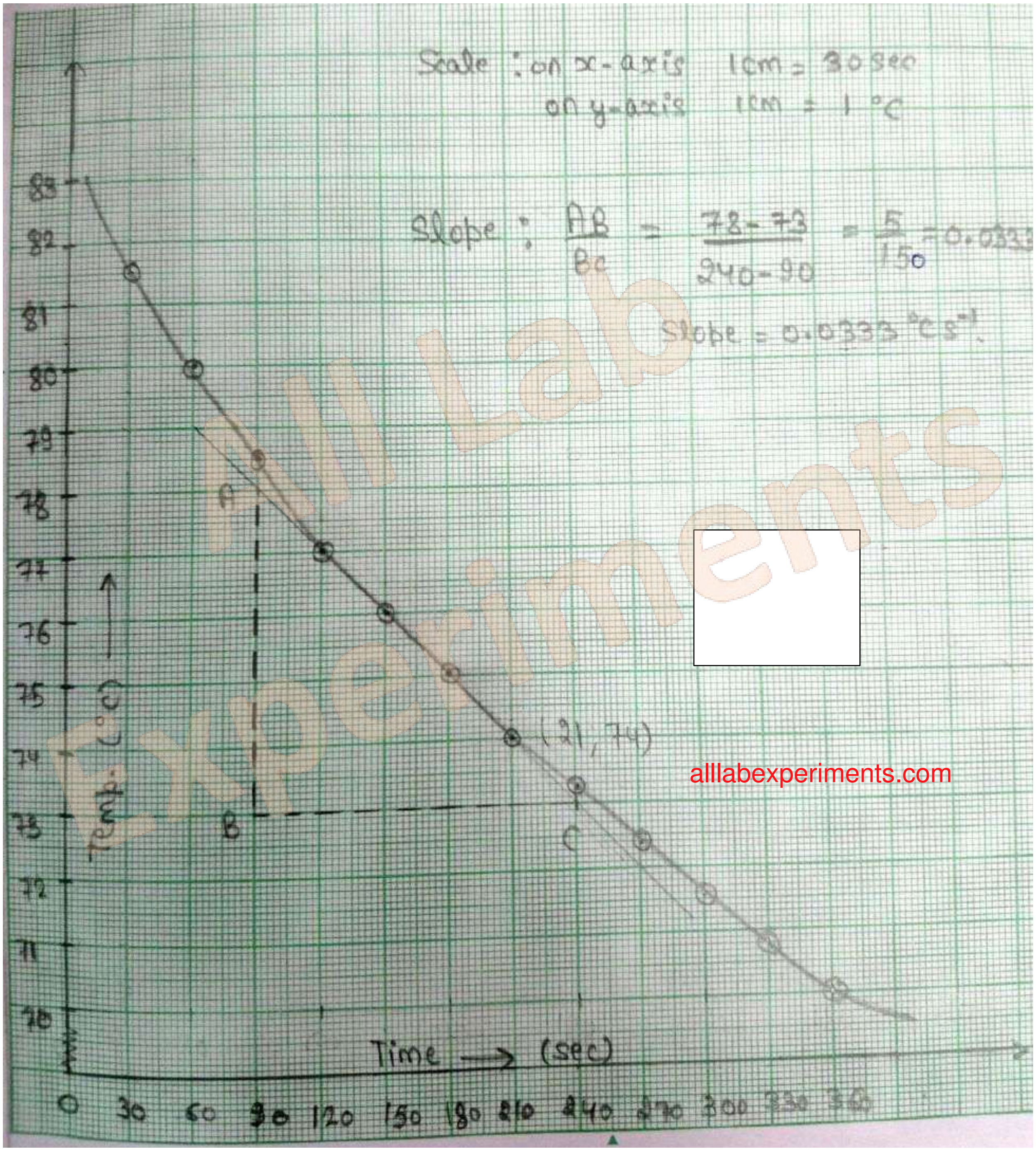
Scale : on x-axis 1cm = 30 sec
on y-axis 1cm = 1 °C
Slope : AB/BC = (78 - 73)/(240 - 90) = 5/150 = 0.0333
Slope = 0.0333 °C s⁻¹
(21, 74)
A
B
C
Temp. (°C)
Time → (sec)
83
82
81
80
79
78
77
76
75
74
73
72
71
70
0
30
60
90
120
150
180
210
240
270
300
330
360

(vi) Note the temp. T of the metal slab B after every 30 sec till its temp. falls to 10°C below T_2.

(vii) Plot a graph with time along x-axis and temp. along y-axis. This gives the cooling cure of B. Draw a tangent to this curve at $T = T_2$°c and determine the slope of the tangent. This gives $\left(\frac{dT}{dt}\right)_{T_2}$.

Result :-

The coefficient of thermal conductivity of the given material is 1.38×10^{-4} cal s^{-1} cm^{-1} °c^{-1}

579.6×10^{-4} J s^{-1} m^{-1} k^{-1}

Actual value = 1.12×10^{-4} cal s^{-1} cm^{-1} °c^{-1} % Error = 23%

Precaution and Sources of Error :-

(i) The diameter and thickness of disc should be carefully determined.

(ii) The steady state should be judged correctly.

(iii) The thermometers used should be sensitive.

(iv) The tangent to the cooling curve to determine dT/dt should be drawn carefully.

(v) The thermometers should be placed close to the faces of the experimental disc, one on either side.

(vi) There should be no air-film between B and D. For this, they should be pressed together tightly.

Weak points :-

① This method is suitable only for measuring the coefficient of thermal conductivity of bad conductors and can not be employed for good conductors as the difference of temp. $(T_1 - T_2)$ would be very small

② The thermometer being a little away from the faces of D, may ... the correct temp. of its faces.