List of Experiments

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine Stefan's Constant.
3. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
4. To determine the coefficient of thermal conductivity of a bad conductor by Lee disc method.
5. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
6. To study the variation of thermo emf across two junctions of a thermocouple with temperature.
7. To calibrate Resistance Temperature Device (RTD) using Null Method/Off-Balance Bridge
8. To determine the thermal Conductivity Of Good Conductor By Forbes Method

Experiment No. 1 Date.

Mechanical equivalent of heat

AIM :

To determine the Mechanical Equivalent of heat (J) by the Callender and Barnes method.

APPARATUS REQUIRED :

A Callender and Barne's calorimeter, AC mains with a step down transformer, an AC Ammeter and an AC Voltmeter, switch, a rheostat, a stop watch, a measuring jar and 2 thermometers.

FORMULA :

$J = (E2C2 - E1\ C1)/(m1 - m2)\ (q2 - q1)\ s$ for water $S = 1.0$ Cal/gm °C.

PROCEDURE :

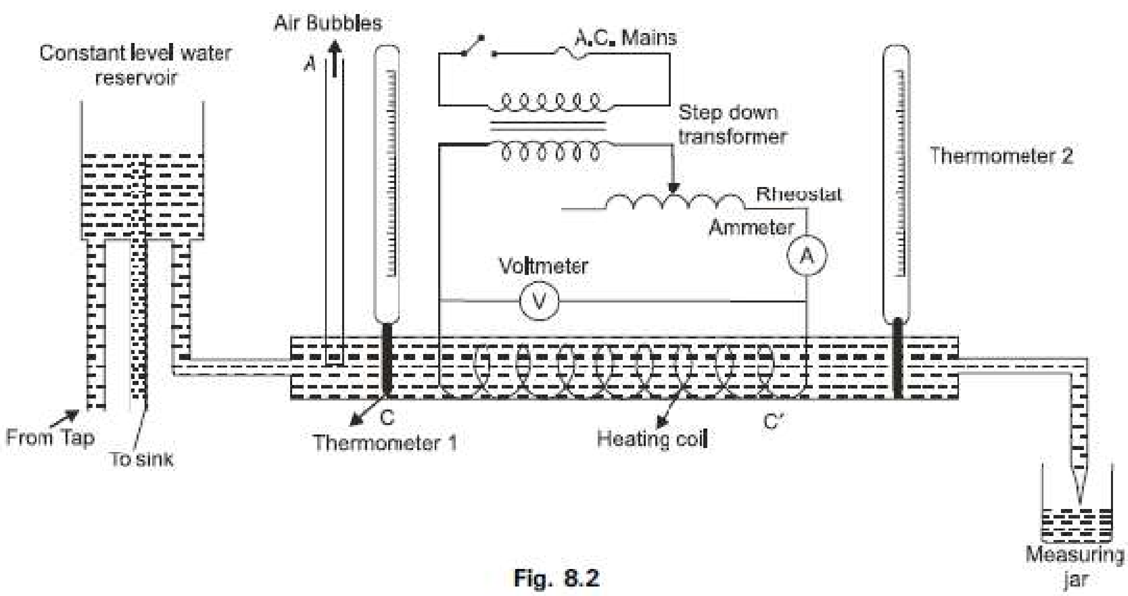


Fig. 8.2

1. Connect the apparatus as shown in the Fig.
2. Adjust the tap and the water reservoir till the rate of flow of water through the tube is about (one) c.c per second.
3. Switch on the current and regulate the rheostat so that the current passing is about 2 amperes.
4. As soon as the temperature of the heated water going out becomes steady. Note the temperature of the two thermometers. Note the ammeter and the voltmeter readings.
5. Measure the rate of flow of water at this moment with the help of measuring Jar.
6. Change the rate of flow of water by varying the height of the reservoir and vary the electric current until the two thermometers again indicate their previous readings. Note the new readings of the ammeter and the voltmeter and measure the new rate of flow of water.

OBSERVATION :

Temperature of the cold water (inlet end) = q1 _ _ _ _ _ºC

Temperature of the hot water (exit end) = q2 = _ _ _ _ _ ºC

	E (in volts)	*C (in amps)*	*Amount of flow of water per minute unit*			
			I	II	III	Mean
I Case						
II Case						

RESULT :

The value of *J* is found to be = -----------ergs/cal. (C.G.S. units)

= -----------Joule/cal. (M.K. S. units)

Experiment No.2 Date.

Determination of Stefan Constant

Aim:
Determination of Stefan constant σ .

Apparatus:
Heater, temperature-indicators, box containing metallic hemisphere with provision for water-flow through its annulus, a suitable black body which can be connected at the bottom of this metallic hemisphere.

$$R = \epsilon\, \sigma\, T^4 \qquad \text{------------------ (1)}$$

5.67x10-8 Wm-2K-4, and T is the temperature in Kelvin scale.
For an ideal black body, emissivity Є=1, and equation (1) becomes,

$$R = \sigma\, T^4 \qquad \text{------------------ (2)}$$

This setup uses a copper disc as an approximation to the black body disc which absorbs radiation from the metallic hemisphere as shown in fig (1). Let Td and Th is the steady state temperatures of copper disc and metallic hemisphere respectively. Now according to the equation (2), the net heat transfer to the copper disc per second is,

$$\frac{\Delta Q}{\Delta t} = \sigma A\,(T_h^4 - T_d^4) \qquad \text{-------------- (3)}$$

Where A is the area of the copper disc and ΔQ= (Qh - Qd).
Now, we have another equation from thermodynamics for heat transfer as,

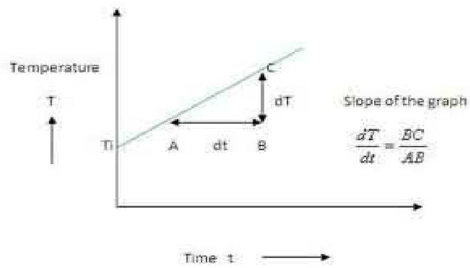
$$\frac{\Delta Q}{\Delta t} = m\, c_p \frac{dT}{dt} \qquad \text{--------------- (4)}$$

Where 'm' mass of the disc, 'C_p'' specific heat of the copper, dT/dt is the change in temperature per unit time. Equating equations (3) and (4),

$$\sigma A\,(T_h^4 - T_d^4) = m\, c_p \frac{dT}{dt}$$

Hence,

$$\sigma = [m\, c_p / A\,(T_h^4 - T_d^4)]\, \frac{dT}{dt}$$



Procedure for performing real lab:

1. Remove the disc from the bottom of the hemisphere and switch on the heater and allow the water to flow through it.
2. Allow the hemisphere to reach the steady state and note down the temperature T1, T2, T3 .
3. Fit the disc (black body) at the bottom of the hemisphere and note down its rise in temperature with respect to time till steady state is reached.
4. A graph is plotted with temperature of disc along Y-axis and time along X-axis as shown.
5. Find out the slope dT/dt from the graph.

Procedure for performing simulator:

1. Choose desirable values of water temperature, surrounding temperature, mass and radius of the disc using the sliders.
2. Click the "Power ON" button and wait till T1, T2 ,T3 reach steady state. Note down its values.
3. Putting T4 button, click "Fit the disc" option.
4. Note down T4 at different intervals of time till it reaches steady state.
5. Plot Temperature-Time graph and determine dT/dt its slope .
6. Determine Stefan's constant σ using the given formula.

Observations:

Trial number	Temperature of the hemisphere			Average Temp $T_h = (T_1+T_2+T_3)/3$	Temperature of the disc in Kelvin T_4	Time t (in sec)	Steady state temperature of the disc in Kelvin T_d
	T_1	T_2	T_3				
1.							
2.							
3.							

Calculations:

Mass of the copper disc = ... kg
Specific heat of copper = ... Jkg-1
Radius of the disc = ... m
Area of the disc = ... m2
Slope of the graph dT/dt = ……Ks-1
Substituting the values in the given expression, = …………………………… Wm-2K-4

Result:

Stefan-Boltzmann's constant σ =……………. $Wm^{-2}K^{-4}$

Experiment No.3 Date.

Thermal Conductivity of Copper - Searles Bar

AIM:

To determine the thermal conductivity of a good conductor such as copper.

APPARATUS REQUIRED :

Searle's bar apparatus, steam generator or power supply (depending on the method of heating the bar), for thermometers (0 - 50oC in 0.1 oC divisions), ruler, measuring cylinder, water tap, rubber tubing, vernier calipers

FORMULA :

Thermal conductivity of copper (k) from:

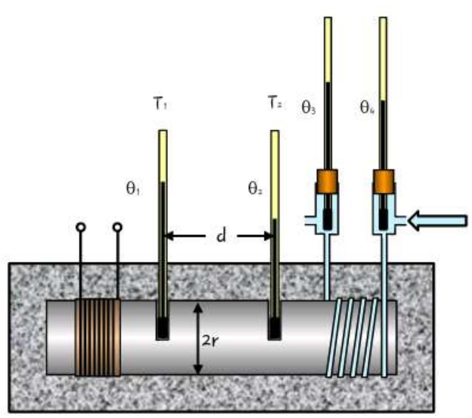
$$k = (C_W\ m\,[\theta_3 - \theta_4]d) / (\pi r^2[\theta_1 - \theta_2]t)$$

where

C_W - specific heat capacity of water
θ_1 ,θ_2 , θ_3 ,θ_4 – Temperature of the thermometers 1,2,3,4 respectively
m – Mass of the tube
t – Time of passing steam
r - diameter of the copper bar
d - distance between the two thermometers

PROCEDURE :

Set up the apparatus as shown and pass steam through the tubes until all four thermometers have reached a steady state, this may take up to 30 minutes. Record the values of the temperatures θ_1 ,θ_2 , θ_3 ,θ_4 .Record the flow rate of the water passing through the cooling tubes, m kg in t seconds. NB this flow should be slow and steady. Measure the diameter of the copper bar (2r) in at least two places and the distance between the two thermometers (T1 and T2) (d).If time allows repeat the experiment.



OBSERVATIONS :

TIME (min)	Θ_1	Θ_2	Θ_3	Θ_4

CALCULATIONS :

specific heat capacity of water C_w = _______ J kg $^{-1}$ k^{-1}

Mass of the tube m = ________ kg

Time of passing steam t = ________ seconds

Diameter of the copper bar r = ________ metre

Distance between the two thermometers d = ______ metre

Thermal conductivity of copper

$$k = (C_W\ m\,[\theta_3 - \theta_4]d) / (\pi r^2[\theta_1 - \theta_2]t)$$

Thermal conductivity of copper k = ________ W m^{-1} K^{-1}

RESULT :

Thermal conductivity of copper k = ________ W m^{-1} K^{-1}

Experiment No.4 Date.

Thermal conductivity of a bad conductor by Lee and charlton's method

Aim:

To determine the coefficient of thermal conductivity of a bad conductor using Lee's disc apparatus.

Apparatus:

Lee's disc apparatus consist of a metallic disc resting on a 5 cm deep hollow cylinder (steam chamber) of same diameter. It has inlet and outlet tubes for steam. In addition, it has radial holes to insert thermometers. Thermal conductivity is the property of a material . It indicates the ability of a material to conduct heat. When steam is passed through the cylindrical vessel a steady state is reached soon. At the steady state, heat conducted through the bad conductor is equal to heat radiated from the Lees disc.

Formula

At the steady state, rate of heat transfer (H) by conduction is given by;

$$H = kA\left[\frac{T_2 - T_1}{x}\right]$$

Where,

k - Thermal conductivity of the sample

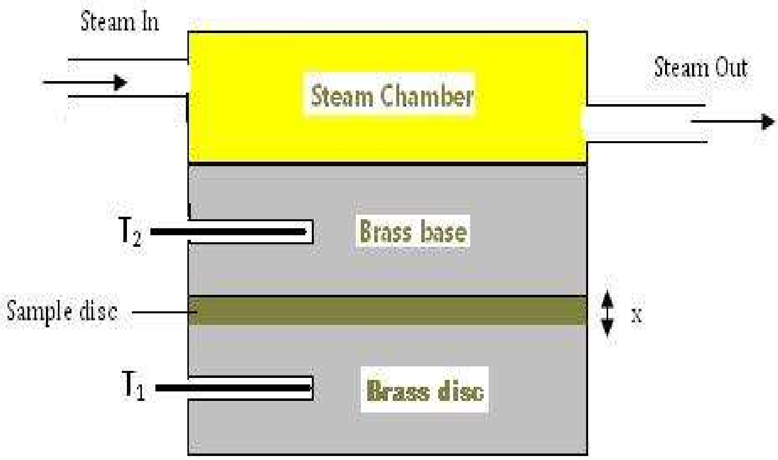
A - Cross sectional area,

T_2 - T_1 -Temperature difference across the sample.

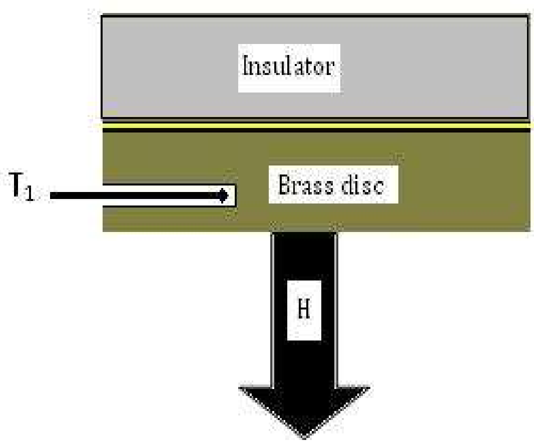
x -Thickness of the bad conductor (see figure 1)

Procedure

The sample is an insulator. It is in the form of a thin disc with large cross sectional area ($A = \pi r^2$) compared to the area exposed at the edge ($a = 2\pi rx$) in order to reduce the energy loss. Rate of energy transfer across the sample can be increased by keeping 'x 'small and 'A 'large. Keeping x small means the apparatus will reach a steady state quickly.



The thin sample of disc is sandwiched between the brass disc and brass base of the steam chamber (see figure 2). The temperature of the brass disc is measured by thermometer T_1 and the temperature of the brass base is measured by thermometer T_2 . In this way the temperature difference across such a thin disc of sample can be accurately measured.



The temperatures T_1 and T_2 are constant when the apparatus is in steady state. Then the rate of heat conducted through the brass disc must be equal to the rate of heat loss due to cooling from the bottom of the brass disc by air convection. By measuring how fast the brass disc cools at the steady state temperature T_1, the rate of heat loss can be determined. It shown in figure 3. If the disc cools down at a rate, $\frac{dT}{dt}$ then the rate of heat loss is given by:

$$H = mc\frac{dT}{dt}$$

Where,

m- mass of the brass disc

c - specific heat capacity of brass.

At steady state, heat conducted through the bad conductor per second will be equal to heat radiated per second from the exposed portion of the metallic disc.

$$kA\left[\frac{T_2 - T_1}{x}\right] = mc\frac{dT}{dt}$$

$$k = \frac{mc\frac{dT}{dt}}{A\frac{(T_2 - T_1)}{x}}$$

Where,

k - Coefficient of thermal conductivity of the sample,

A - Area of the sample in contact with the metallic disc,

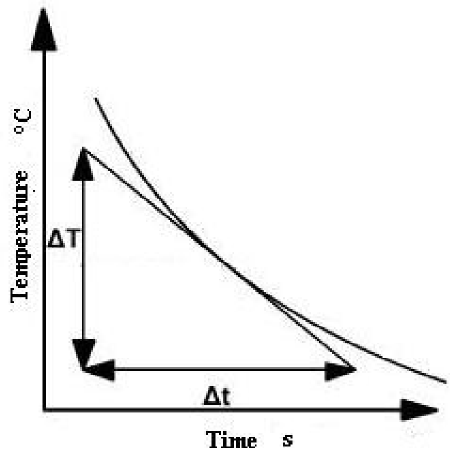
x - Thickness of the sample,

T_2- T_1 -Temperature difference across the sample thickness,

m - Mass of the metallic disc,

c - The Heat capacity of the metallic disc,

dT/dt - Rate of cooling of the metallic disc at T_2.



Result:

The coefficient of thermal conductivity of a bad conductor is ___________________.

Experiment No.5 Date.

Platinum Resistance Thermometer

AIM :

To determine the temperature co-efficient of resistance by Platinum resistance thermometer.

APPARATUS REQUIRED :

Carey Foster's Bridge ,Two equal resistances of about 2 ohms each, Thick copper strip, A fractional resistance box, A cell / battery, Galvanometer, Platinum Resistance Thermometer, Water bath, Thermometer, One way key, Connecting wires, Jockey .

Formula

$Q = (R_2-R_1) / (T_2R_1-T_1R_2)$

PROCEDURE :

The experiment is performed in two parts.

Part I Determination of resistance per unit length (*ρ*) of the Carey Foster's Bridge wire

The procedure to find the resistance per unit length of the bridge wire is explained in the experiment CAREY FOSTER BRIDGE.

Part II Determination of the resistance of PRT at different temperatures (*R*T)

1. Connect the circuit as shown in Figure 2 above.
2. Put the PRT in water bath and connect the PP leads in gap 1 and the compensating leads (C, C) in gap 4 in series with a fractional resistance box X. The wires used to connect the (P, P) and (C, C) leads should be cut from the same bunch and should be of equal length.
3. Connect the two standard resistances P and Q in the inner gaps 2 and 3 and also, the galvanometer with a jockey as shown in Figure.
4. Put some crushed ice in the water bath and note the temperature T1. Ensure that the PRT is surrounded by crushed ice with a little water so as to fill all air spaces between the ice pieces. This will ensure uniform temperature for the PRT.
5. Introduce a suitable resistance from the fractional resistance box X (0.5 or 1.0 Ω) and note down the balancing length from one end as *l1*. The **balance point** should be determined only after the PRT has acquired a steady temperature failing which, the position of balance point on the bridge wire will not be stable. Also record the same for reverse current by interchanging the terminals of the battery.
6. Interchange the resistances in the outer arms (i.e. gaps 1 and 4) and note *l2* from the same end for direct as well as reverse current.

7. Calculate $R1 = X + \rho\ (l2 - l1)$; that is the resistance of the PRT at temperature T1.
8. Now, remove the ice and put the PRT in water at room temperature, say T2. Note down and record T2 in the observation table
9. Determine the resistance of PRT at $T2$ (that is $R2$) by repeating the steps 5 – 7 as above.
10. Now, heat the water for some time till the PRT acquires a constant temperature $T3$. Note down $T3$ and repeat the steps 5 – 7 to determine the resistance at T3.
11. Repeat step 10 for at least five more temperatures.

OBSERVATIONS :

Table 1 : Determination of ρ

S. No.	X (Ω)	Position of balance point with Cu strip in the						l'_2-l'_1 (cm)	$\rho = X/(l'_2 - l'_1)$ (Ωcm^{-1})
		Right gap (l'_1 in cm)			Left gap (l'_2 in cm)				
		Direct current	Reverse current	Mean	Direct current	Reverse current	Mean		

Mean ρ = ---------
Ωcm-1

Table 2: Determination of resistance of PRT at different temperatures
Resistance per unit length of the bridge wire, ρ = ------ Ω cm-1
Fractional resistance = 0.5 or 1.0 Ω

S. No.	Temp. of water (°C)	Position of balance point with PP leads in the						l_2-l_1 (cm)	$R_T = X - \rho\ (l_2 - l_1)$ (Ω)
		Right gap (l_1 in cm)			Left gap (l_2 in cm)				
		Direct current	Reverse current	Mean	Direct current	Reverse current	Mean		

CALCULATIONS :

Plot a graph (Figure 2) between the temperature (in oC) and the resistance of PRT (in Ω) that is the calibration curve of the PRT.

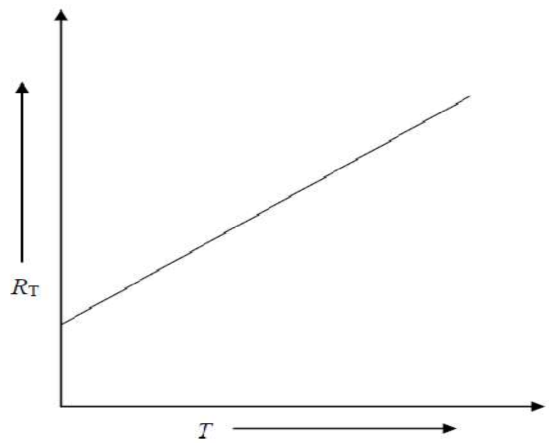


Figure 3: Graph showing change in resistance with temperature

From the graph, ∝ can be calculated

RESULT:

The temperature coefficient of resistance for platinum using PRT is found to be ------------

Experiment No.6 Date.

Variation Of Thermo Emf

AIM :

To study the variation of thermo emf across two junctions of a thermocouple with temperature.

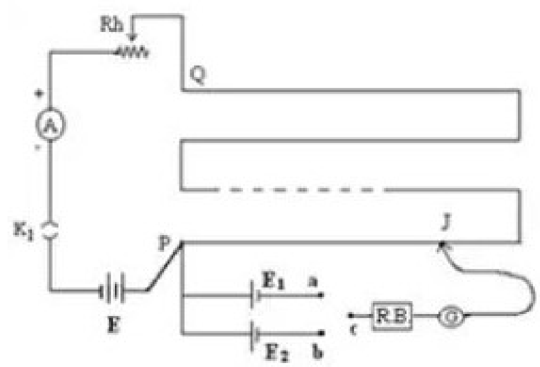
APPARATUS REQUIRED :

Potentiometer, Daniel cell, Battery eliminator, Resistance box, Leclanche cell, Jockey, Galvanometer, one way key, two way key, rheostat, ammeter

FORMULA

$$E_1 / E_2 = L_1 / L_2$$

CIRCUIT DIAGRAM :



PROCEDURE :

Arrange the required materials on a table and make the connections as per the connection diagram. Tight the plugs of the resistance box. Note the reading on the ammeter. To test the connection, insert plug in the one way key k1 and also in between the terminals a and c of the two way key. Introduce a sufficiently high resistance on the resistance box (R.B). Place the jockey at the two end points of the wire. Press the jockey at both end of the potentiometer wire and note the deflection in galvanometer. If the galvanometer shows opposite deflection, the connections are correct. Now, gently slide the jockey along the potentiometer wire and stop when null point is obtained. Measure the length l1between this point and the end P of the potentiometer. It is the balancing length for the cell E1.Disconnect the cell E1 by removing the plug from the gap ac of the two way key and connect the cell E2by inserting plug into the gap bc of the two way key. Again slide the jockey along the potentiometer wire to obtain the null point. Measure the new balancing length l2 for the cell E2 based on this point. Make sure that the reading on the ammeter is constant throughout the observation. Repeat the experiment by increasing the current by adjusting the rheostat and record the observations. Each time, the ratio between the emf's of the given cells can be calculated using the relation,

$$E_1 / E_2 = L_1 / L_2$$

Simulator Procedure : (As performed through Online Labs Select the first primary cell form the drop down list. Select the second primary cell form the drop down list. Select the rheostat resistance using the slider. In the case of other cells, you can select the emf of the first and second cells using the slider. To see the circuit diagram, click on the 'Show circuit diagram' check box seen inside the simulator window. Connections can be made as seen in the circuit diagram by clicking and dragging the mouse form one connecting terminal to the other connecting terminal of the devices to be connected. Once all connections are made, click and drag the one way key to insert it into the switch. Drag the plug and insert it in the first gap of the two way key. Slide the jockey along the potentiometer wire to obtain the null point. You can see the first balancing length in the popup. Now drag the plug and insert it in the second gap of the two way key. Slide the jockey along the potentiometer wire to obtain the null point. You can see the second balancing length in the popup. You can compare the emf values of the two cells using the value of first and second resonating lengths. You can repeat the experiment by increasing the current by adjusting the rheostat. To verify your result click on the 'Show result' check box. To redo the experiment, click on the 'Reset' button.

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S.No	Ammeter reading (A)	Balancing length when		$E_1 / E_2 = L_1 / L_2$
		E_1 in the circuit L_1 (cm)	E_2 in the circuit L_2 (cm)	

CALCULATIONS :

Calculate the ratio of E1 and E2 for each set of l1 and l2. The mean of the calculated values gives the ratio of emf's of the two given primary cells

RESULT :

The emf's of the two given primary cells are compared.

The ratio of emf's of the two given primary cells, E1/E2 =.............

Experiment No.7 Date.

Calibration of Resistance Temperature Device

AIM :

To calibrate Resistance Temperature Device (RTD) using Null Method/Off-Balance Bridge.

APPRATUS REQUIRED :

RTD sensor, Constant temperature bath, Precise thermometer, Digital multi-meters (2)

FORMULA

The basic relation for the electric resistance variation with temperature for RTD is given by

$$R_{RTD} = R_o[1+\alpha(T-T_o)] \quad \text{------------------ (1)}$$

where

RRTD is the electric resistance of the RTD, [Ω]

Ro is the electric resistance of the RTD at the reference temperature To, [Ω]

T is the temperature, [°C]

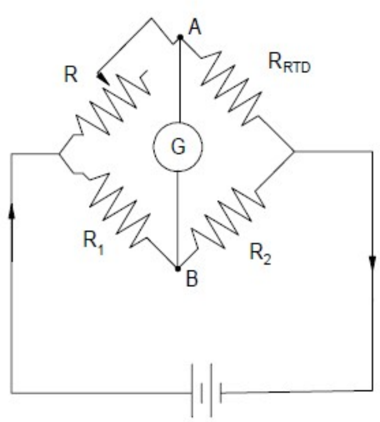
To is the reference temperature, [°C]

α is the temperature coefficient of resistively, [1/°C]

Typical example of α for platinum is 0.00385 1/°C. Notice that the sensitivity coefficient for RTD is given by

$$K_{RTD} = R_o\alpha \quad \text{----------------- (2)}$$

Again for typical platinum RTD, the sensitivity coefficient is bout 0.4 Ω/°C, which means that the sensitivity is very small i.e. for 1°C change, the resistance changes by 0.4Ω . For this reason, in order to measure the resistance RRTD correctly, Wheatstone bridge is use. A typical Wheatstone bridge is shown on Figure 1 below.



The bridge is balanced when the voltage between the point A and B in figure 1 is null. This can be achieved by changing the variable resistance R. When the bridge is balanced the four resistance are related together by the following equation

$$\frac{R}{R_{RTD}} = \frac{R_1}{R_2} \qquad \text{-------------- (3)}$$

Notice that if R1=R2, then RRTD=R.

It is to be noted that some RTD sensors come with three or four wire leads to reduce the effect of self heating when measuring the RTD resistance. For our experiment since we have short leads, the resistance RTD will be measured directly using a precise digital multi-meter. The relationship on the other hand for the thermistor resistance with temperature is given by

$$R_T = R_o e^{\beta\left[\frac{1}{T} - \frac{1}{T_o}\right]} \qquad \text{-------------------------- (4)}$$

where
RT is the thermistor resistance at temperature T, [Ω]

Ro is the resistance at the reference temperature To, [Ω]

T is the temperature at which the resistance is RT, [K]

To is the reference temperature, [K]

β is the material constant [1/K]

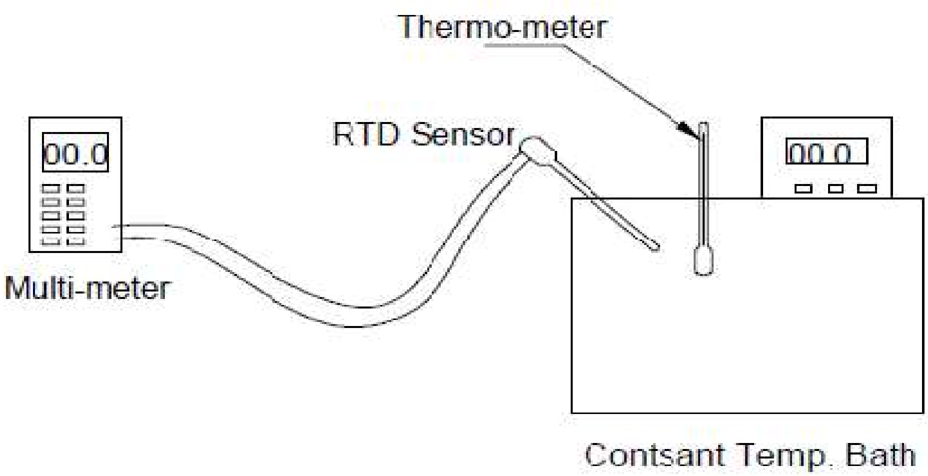
Unlike RTD there is no need to use Wheatstone bridge when measuring the resistance of the a thermistor RT. Also to be noted that the variation of the thermistor resistance with temperature is not linear as can be seen from equation 4.

In this experiment, the values of α, and β will be determined, along-with fundamental equations similar to equations 1 and 4 above for RTD and the thermistor respectively.

PROCEDURE :

The experiment setup is shown in Figure 2 below. The temperature of the constant temperature bath can be set to be any desire temperature as long as it is in the range of operation of the unit. [For laboratory experimental bath such the one we have in our laboratory the operational temperature range is between 10 and 80°C]. There is an indicator on the bath that shows the set point temperature and the actual fluid temperature. The procedural steps for the experiment are:

1-Insert the RTD sensor and the thermistor sensor inside the constant temperature bath
2-Take the RTD leads (only two will be used) to the Digital multi-meter to measure the RTD resistance, RRTD. Do the same thing for the thermistor to measure the thermistor resistance RT using another digital multi-meter.
3-Turn on the constant temperature bath on. Set the liquid temperature to 10 °C.



4-When the liquid temperature reaches the set point temperature as indicated on the temperature display, measure RRTD, and RT. In case a precise thermometer is available, insert it in the proper hole on the top of the liquid bath and record also the thermometer reading when steady state condition is prevailed. Record the measured data in Table 1 below.

5-Change the setup fluid temperature to another temperature and repeat step 4. It is recommended to start with a temperature of 10°C, and increase T by 5°C each step for 7 to 8 readings.

OBSERVATIONS :

Table 1 Measure data for RTD calibration.

No	T_{set} [° C]	T_{bath} [°C]	T_{therm} [C]	R_{RTD} [Ω]	R_T [kΩ]
1					
2					
3					
4					
5					
6					
7					
8					

RESULT :

The given Resistance Temperature Device has been calibrated.

Experiment No.8 Date.

Thermal Conductivity of Good Conductor by Forbes Method

AIM:

To measure the thermal conductivity of good conductors such as Aluminium, Copper, Brass, etc. by following Forbes method.

APPRATUS REQUIRED :

(a) A long rod of uniform cross sectional area whose thermal conductivity 'K' is to be measured, with grooves at an interval of 10 cm to mount the thermometers, (b) Mercury thermometer(c) a small sample length (10 cm) of same material (preferably cut from the same rod).(d) A heater or boiling water bath (e) stop watch .

FORMULA:

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

$$Q_1 = K A \left(\frac{dT}{dx}\right)_B \qquad \text{............... (1)}$$

where K is the thermal conductivity of the material, A is the area of cross-section of the material, $\left(\frac{dT}{dx}\right)_B$ is the change in temperature per unit length of the rod at B.

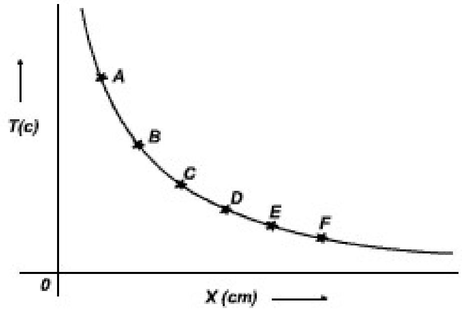
PROCEDURE :

1.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.

2.Measure the temperatures at the points A, B, C, etc. and tabulate the reading. Draw the graph of T(0C) as a function of horizontal distance such as O to A, O to B etc. The typical graph would be as shown in Figure 2.

3. Find the slope of the curve at two points, such as B and E, by drawing tangential lines to the curve at points B and E. They

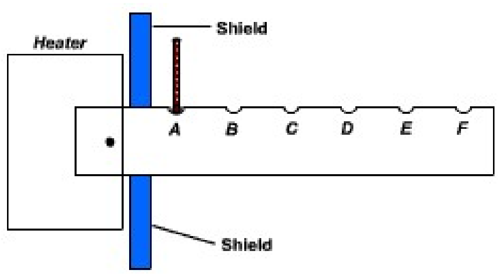
are taken as $\left(\frac{dT}{dx}\right)_B$ and $\left(\frac{dT}{dx}\right)_B$ respectively.



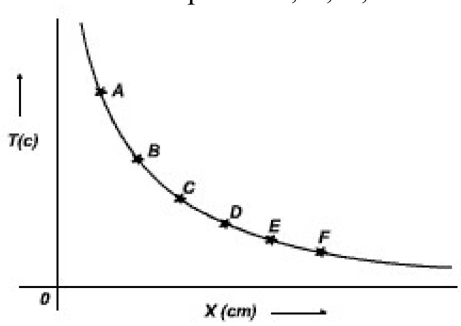
4. Heat the sample rod using a heater or boiling water bath for a sufficient time to reach a steady state. Take out the sample rod, hang it using a string and stand. Insert the thermo couple or thermometer into the groove as shown in Figure 3.

5. Measure the temperature as a function of time at regular interval, using a stop watch and the thermometer. Tabulate them as suggested in table2. Plot a graph of T versus time. The typical plot of T versus time is given in Figure 4

6.By comparing Figure 2 and Figure 4 spot the points A, B, C, D, etc in Figure 4 and mark them.



7. Find the slopes dT / dt at the points A, B, C, D etc. from the Figure 4.



8.Plot dT / dt verses x. The typical graph is shown in Figure 5

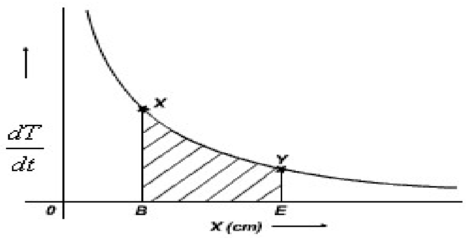
9. Mark two points x and y on the graph corresponding to the position B and E. Determine the area under the curve X, Y, i.e BXYE in Figure 5.

Area BXYE = $\int_B^E \frac{dT}{dt} dx$ .... (7)

10. Thermal conductivity K can be calculated using eq. (6) and (7).

i.e. $K = \frac{\rho C \ (Area\ BXYE)}{\left(\frac{dT}{dx}\right)_B - \left(\frac{dT}{dx}\right)_E}$ ...... (8)

Note that instead of B and E, any two pair of points can be taken and accordingly the eq. (8) can be modified



OBSERVATIONS :

Table 1 :

Sl. No	Distance from the hot end	Position	Temperature T (°C)
1			
2			
3			
4			
5			
6			

Table 2 :

Sl. No	Time	Temperature T (°C)

Table 3 :

Sl. No	Position	Distance from the hot end	$\frac{dT}{dx}$

RESULT :

The thermal conductivity of given material = ________ W/mK