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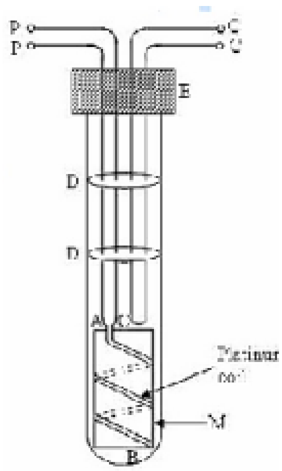
General Properties of Matter Lab
PH29001

EXPERIMENT-8
PLATINUM RESISTANCE THERMOMETER

Aim: To determine the temperature coefficient of resistance of platinum by means of Carey Foster's bridge and to an unknown temperature.

Apparatus: Platinum resistance thermometer, Foster's bridge, a galvanometer, beaker (600 cc capacity), electric stove, two identical resistances, one fractional resistance box, a mercury thermometer, one power source and connection wires.

Theory: The resistance of all metals increases with increase in temperature but for Pt. This increase is very high in comparison to other metals. If R_0 is the resistance of a given Platinum wire at temperature 0℃ and R_t at t℃, then - $R_t = R_0(1+\alpha t + \beta t^2 + \ldots.)$ ...(1)
α and β are constants whose values are $3.94 \times 10^{-3}\ C^{-1}$ and $-5.8 \times 10^{-7}\ C^{-2}$.
When temperature is not very high, then variation of resistance with temperature is almost linear and the above equation can be written as - $R_t = R_0(1+\alpha t)$ ...(2)



In Carey Foster's bridge the part of wire remains inside the metal strip (End error). Let these be x and y cm respectively. To determine x and y two different suitable resistance R_1 and R_2 is put in gap-1 and gap-2 during this the gap-3 will be closed with metal strip. In this arrangement if null points come for length l, we can write -

$$\frac{R_1}{R_2} = \frac{(x+l)}{(y+100-l)} \ \ldots (3)$$

If we alter R_1 and R_2 is in their places and the null point is obtained at l_1, then the above equation can be written as -

$$\frac{R_1}{R_2} = \frac{(x+l')}{(y+100-l')} \ \ldots (4)$$

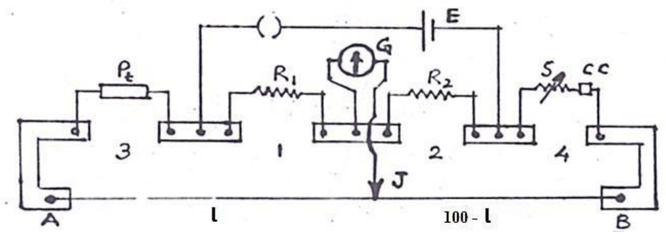
Here, ρ is the resistance per unit length of the meter bridge wire.
Now from equation (3) & (4) x and y can be evaluated.
To find ρ, two equal resistances (say, each of 5Ω) are put in gap-1 and gap-2, one can choose different resistance also. And a small resistance (s) is put in gap-4 as shown in

figure-3. During this, the gap-3 will be closed with a metal strip.
In this arrangement if null points come for length L, we can write -

$$\frac{R}{R} = \frac{(x+L)}{(y+100-L)+s} = \frac{s}{(x-y)+(2L-100)} \;\ldots (5)$$

Now, two equal resistances (say, each of 5 Ohm) are put in gap 1 and gap 2 and the Platinum thermometer (resistance R_t) in gap-3 are connected and in gap-4 the compensating lead of platinum resistance thermometer with another fractional resistance box S is connected in series. In this situation if null point is at L_1, then it can be written as-

$$\frac{R}{R} = \frac{R_t+(x+L_i)\rho}{\rho(y+100-L_i)+s} \quad R_t = S + (y - x)\rho + (100 - 2L_1)\rho \;\ldots (6)$$



On plotting **t−R$_t$** , for boiling ice, room temperature and boiling water, it will be straight line.

Observations:

- Least count of meter-scale = 0.1 cm.

Table-1-

DETERMINATION OF TERMINAL RESISTANCE

Sl. No.	$R_1\Omega$	$R_2\Omega$	l cm	(100-l) cm
01	5.2	5.2	48.6	51.4
02	5.2	1.2	86.6	13.4

Calculations-

Using equations (3) and (4), the values of x and y can be evaluated.

$$\frac{R_1}{R_2} = \frac{(x+l)}{(y+100-l)} \;\ldots (3) \text{ and } \frac{R_1}{R_2} = \frac{(x+l')}{(y+100-l'\;)} \;\ldots (4)$$

$$\frac{5.2}{5.2} = \frac{(x+48.6)}{(y+51.4)} \;\ldots (3) \text{ and } \frac{5.2}{1.2} = \frac{(x+86.6)}{(y+13.4)} \;\ldots (4)$$

$x - y = 2.8 \; - (3)\; and\; 3x - 13y = - 85.6 \; - (4)$

They are respectively, $x = 12.2\ cm\ and\ y = 9.4\ cm.$

Table-2-

DETERMINATION OF ρ (RESISTANCE PER UNIT LENGTH OF METER BRIDGE WIRE)

$R_1\Omega$	$R_2\Omega$	$S\ (\Omega)$	L cm	(100-L) cm
5.2	5.2	0.5	53.1	46.9

Calculations-

Using equation (5), the value of ρ can be evaluated.

$$\rho = \frac{s}{(x-y)+(2L-100)} = \frac{0.5}{(12.2-9.4)+(2(53.1)-100)} = 0.05556\Omega m$$

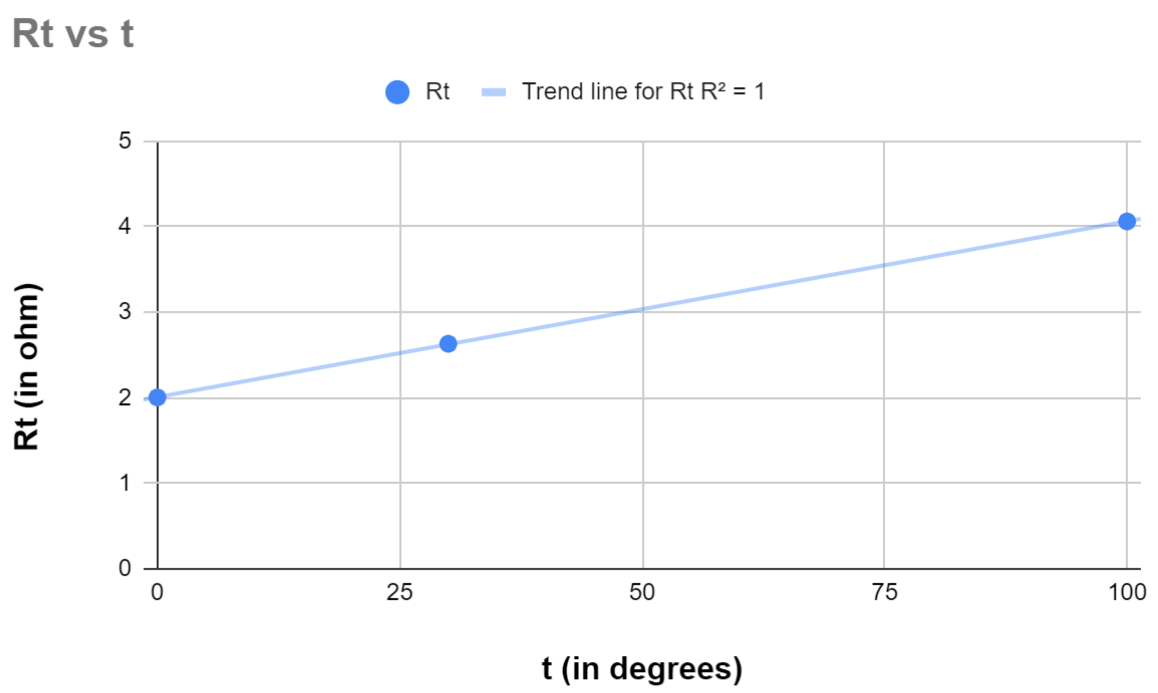
They are respectively, $\rho = 0.05556\Omega m$

Table-3-

Sl. no.	$T\,^oC$	$R_1\Omega$	$R_2\Omega$	L_1 cm	(100-L_1)cm	$S\ (\Omega)$	R_t	Average $R_t\ (\omega)$
1	$0\,^oC$	5.2	5.2	34.9	65.1	0.5	2.007	2.004
		5.2	5.2	39.5	60.5	1	2.001	
2	$30\,^oC$	5.2	5.2	28	72.0	0.5	2.766	2.631
		5.2	5.2	35	65.0	1	2.496	
3	$100\,^oC$	5.2	5.2	16	84.0	0.5	4.086	4.061
		5.2	5.2	21	79.0	1	4.036	
4	unknown	5.2	5.2	22	78.0	0.5	3.426	3.401
		5.2	5.2	27	73.0	1	3.376	

Graphs

Graph of observation table-3-



Scale-

- X-axis: 1 unit = 25^oC
- Y-axis: 1 unit = 1Ω

Calculation-

From the graph, we can write the equation of the graph of the form - $y = mx + c$since it's a

straight line. Hence, its slope
$= m = 0.02054493671$ $and\ its\ intercept\ = c = 2.008386076.$
Therefore, its equation is - $y = 0.02054493671x + 2.008386076\ \ - (I).$
The unknown temperature can be found from the above equation$-$ (I). We know that
$R_t = 3.401\Omega.$
$3.401 = y = 0.02054493671x + 2.008386076$
$x = t = 67.7838021$°C.
Therefore, the unknown temperature is 67.78°C.
At different temperatures, the value of α can be calculated using the formula below-

$$\alpha_1 = \frac{(R_2 - R_1)}{(T_2R_1 - T_1R_2)}$$

$$\alpha_2 = \frac{(R_3 - R_2)}{(T_3R_2 - T_2R_3)}$$

$$\alpha_3 = \frac{(R_1 - R_3)}{(T_3R_1 - T_1R_3)}$$

The temperature coefficient of resistance of platinum by means of Carey Foster's bridge is α.

$$\alpha = \frac{\alpha_1 + \alpha_2 + \alpha_3}{3}$$

$\alpha_1 = 0.01042914172, \alpha_2 = 0.01012246054\ and\ \alpha_3 = 0.0101804752$
Therefore, substituting the above values, we get -

$$\alpha = \frac{\alpha_1 + \alpha_2 + \alpha_3}{3} = 0.01024402582\ per\ °C.$$

Therefore, the temperature coefficient of resistance of platinum by means of Carey Foster's bridge is $0.010244\ per$ °C.

Error Analysis-

<u>Finding error in temperature(t)-</u>

We know, $y = mx + c$ where $R_t = y\ and\ x = t,\ x = \frac{y-c}{m}$
$ln(x) = ln(y - c) - ln(m)$

$$\frac{\Delta t}{t} = \frac{\Delta(y-c)}{(y-c)} + \frac{\Delta m}{m}$$

We know that, $m = \frac{R}{t}, \Delta m = \Delta R + \Delta t$

$$\frac{\Delta t}{t} = \frac{2\Delta R}{R_t - R_0} + \frac{\Delta R + \Delta t}{m}$$

$$\Delta t(\frac{1}{t} - \frac{1}{m}) = \frac{2\Delta R}{R_t - R_0} + \frac{\Delta R}{m}$$

$$\Delta t = \Delta R\left(\frac{\frac{2}{R_t - R_0} + \frac{1}{m}}{\frac{1}{t} - \frac{1}{m}}\right)$$

We know that,

$R_t = S + (y - x)\rho + (100 - 2L_1)\rho$, therefore, $\Delta R = \Delta\rho + \Delta l$

and also, we know that $\rho = \frac{s}{(x-y)+(2L-100)}$ therefore, $\frac{\Delta\rho}{\rho} = \frac{\rho\Delta l}{S}$

$$\Delta R = \frac{\rho^2 \Delta l}{S} + \Delta l$$

Putting in the values of $\rho = 0.05556\Omega m,\ S = 0.5\Omega, \Delta l = 0.1$ in the above equation, we get-

$$\Delta R = 0.1006$$

$$\Delta t = (0.1006)\left(\frac{\frac{2}{3.401-2.004} + \frac{1}{0.02054493671}}{\frac{1}{67.7838021} - \frac{1}{0.02054493671}}\right) = 0.1036°\mathrm{C}$$

$$\frac{\Delta t}{t} = \frac{0.103590339}{67.7838021} = 1.52824 \times 10^{-3}$$

$$\frac{\Delta t}{t} \times 100 = 0.1528\% \approx 0.15\%$$

Therefore, the maximum percentage error in t is 0.15%.

Result-

1. The value of the unknown temperature is (t) = (67.7838 ± 0.1036) °C.
2. The maximum percentage error in t is 0.15%.
3. The temperature coefficient of resistance of platinum by means of Carey Foster's bridge is $0.010244\ per$ °C.

Precautions-

1. Ensure that the pendulum oscillates in a vertical plane and that there is no rotational motion of the pendulum.
2. The ends of connecting wires, thick copper strips and leads for the resistance box should be cleaned so that no additional contact resistance is introduced.
3. The plugs of the fractional resistance box should be kept tight to avoid undesirable contact resistance.
4. Do not pass current through bridge wire for a long time to minimize change in its resistance.
5. The bulb of the PRT should be properly immersed to obtain correct resistance at any temperature.
6. To reduce statistical error in measurements, at least 3-5 readings must be taken.
7. Zero error must be noted in the measuring instruments.
8. Parallax and back-lash errors during measurement must be avoided.

Discussions-

1. The bridge circuit that can calculate medium resistances or can compare and measure the two large/equal resistance values with small variations is known as Carey foster bridge. It is the modified form of Wheatstone's bridge circuit. It is also referred to as the method of small resistances.
2. The Carey foster bridge principle is simple and similar to Wheatstone's bridge working principle. It works on the principle of null detection. That means the ratios of the resistances will be equal and the galvanometer records zero where there is no current flow.
3. <u>Advantages of Carey foster bridge-</u>
   a. The complexity of the bridge circuit is reduced because there is no need for additional equipment except the slide wire and the resistances.
   b. It can be utilized as the meter bridge where the slide wire length can be increased by connecting resistances in series. Hence the accuracy of the bridge circuit is increased.
   c. Construction is simple and easy to design
4. <u>Applications of Carey foster bridge-</u>
   a. It is used to calculate the values of medium resistances
   b. It is used to compare the approximate values of equal resistances
   c. It is used to measure the value of the specific resistance of the slide wire. > Used in light detector circuits.
   d. Used to measure the intensity of light, pressure, or strain. Since it is a modified form of Wheatstone's bridge.