EXPERIMENT NO. 3
NEWTON'S LAW OF COOLING

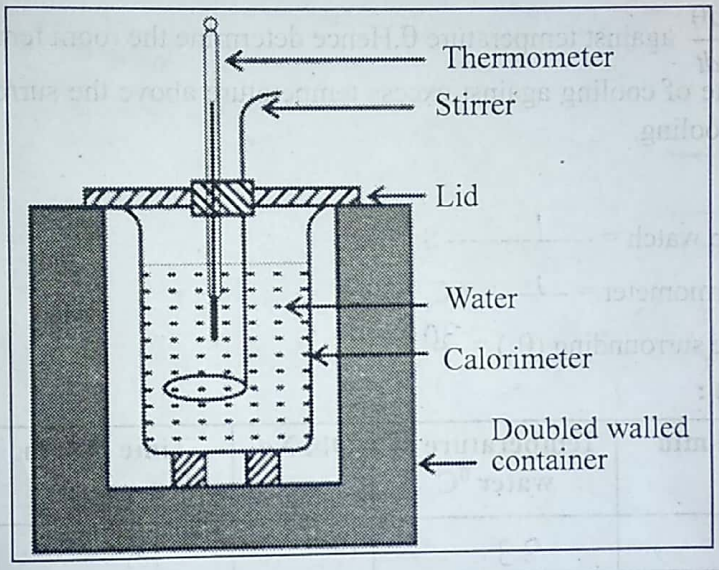
Aim: To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

Apparatus : A thimble or calorimeter, constant temperature enclosure, a thermometer, stop clock, hot water bath etc.

Newton's law of cooling :

The rate of fall of temperature $\left(\frac{d\theta}{dt}\right)$ by a body is directly proportional to the difference of temperature $(\theta - \theta_0)$ of the body over the surroundings, provided the difference is small.

Diagram :



Theory:

The rate at which a hot body loses heat is directly proportional to the difference between the temperature of the hot body and that of its surroundings and depends on the nature of material and the surface area of the body. This is newton's low of Colling

Rate of loss of heat $\frac{d\theta}{dt} = k\,(\theta - \theta_0)$

Where, K = is the constant of proportionality $K = \frac{K'}{ms}$

$$\frac{d\theta}{dt} = ms\frac{d\theta}{dt}$$

$$\therefore ms\frac{d\theta}{dt} = -K'(\theta - \theta_0)$$

$$\therefore \frac{d\theta}{dt} = -\frac{K'}{ms}(\theta - \theta_0)$$

Formula : $\frac{d\theta}{dt} = -K\,(\theta - \theta_0)$

K' = k/ms is another constant it is water equivalent of the calorimeter negative fig indicates that loss of heat implies temperature decrease.

Procedure : experiment without wooden box.

1. Heat the water in water bath.

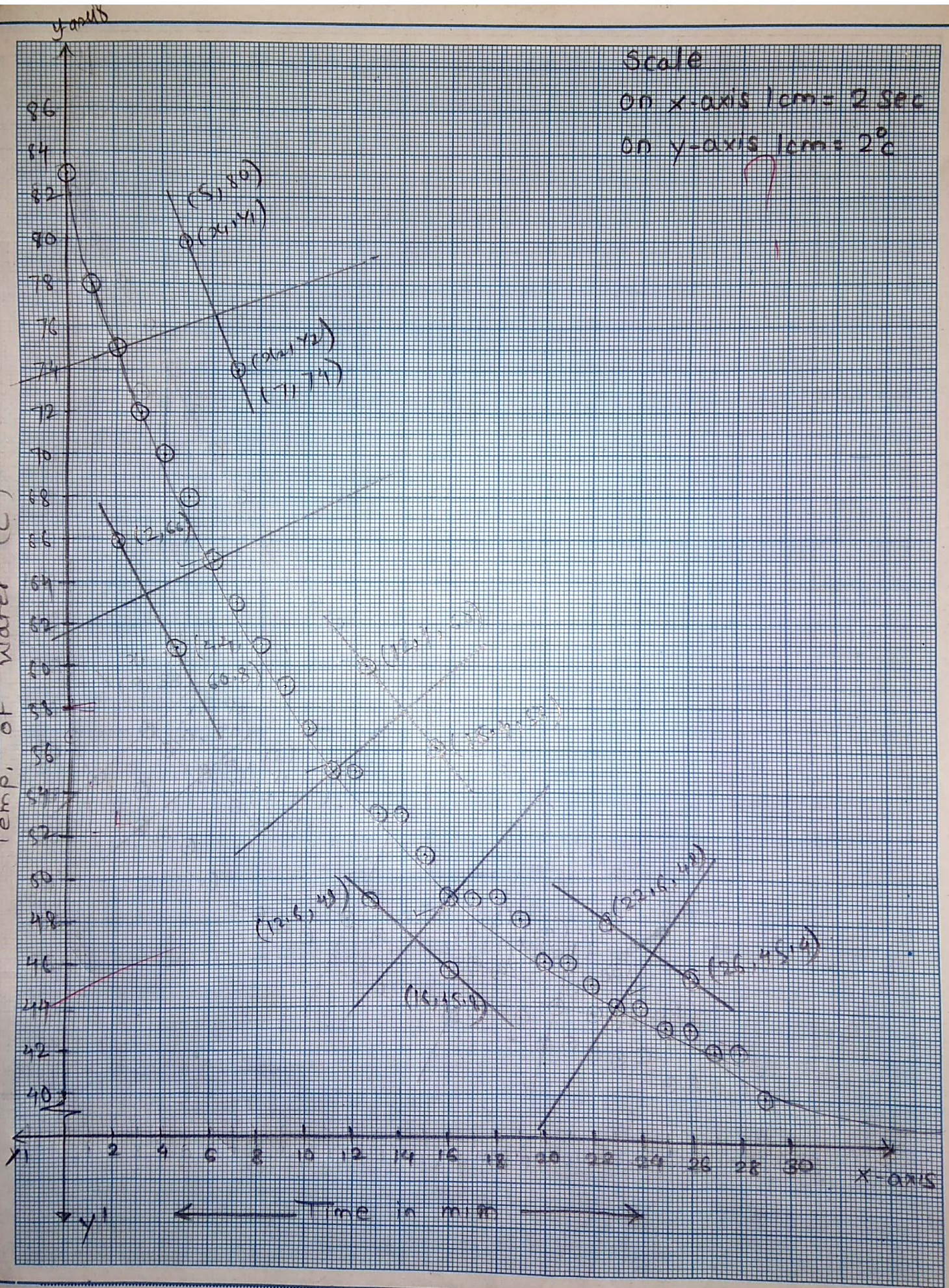
2. Note down the temperature of the surrounding (room temperature) by using thermometer.
3. Fill the thimble or calorimeter with hot water about 75 to 80°C upto $\frac{3}{4}^{th}$ of its capacity. Insert thermometer such that its bulb is well inside the hot water.
4. Note the initial temperature which is about 750 to 80°C above the room temperature.
5. start the stop watch.
6. Note the temperature after every minutes.
7. Take required number of readings till temperature of water falls about 40°C.
8. Plot the graph of temperature (θ^0,C) against time (t) in minutes. Draw smooth curve through the points.
9. Plot the graph of $\frac{d\theta}{dt}$ against temperature θ.Hence determine the room temperature (θ_0).
10. Plot a graph of rate of cooling against excess temperature above the surrounding Hence verify Newton's law of cooling.

Observations :

1. Least count of stop watch = ----1-------- S.
2. Least count of thermometer = --1-------°C.
3. Temperature of the surrounding (θ_0) = 30 °C.

Observation Table (I) :

Ob. No.	Time in min	Temperature of water ^{0}C	Ob. No.	Time in min	Temperature of water ^{0}C
1	0	83	16	15	51
2	1	78	17	16	~~50~~ 49
3	2	75	18	17	49
4	3	72	19	18	49
5	4	70	20	19	48
6	5	68	21	20	46
7	6	65	22	21	46
8	7	63	23	22	45
9	8	61	24	23	44
10	9	59	25	24	~~45~~ 44
11	10	57	26	25	43
12	11	55	27	26	43
13	12	55	28	27	42
14	13	53	29	28	42
15	14	53	30	29	40



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i) To determine, $\frac{d\theta}{dt}$ for 5 different temp's

i) for $\theta = 75^\circ$, $\left(\frac{d\theta}{dt}\right)_{75^\circ} = \left|\frac{y_2 - y_1}{x_2 - x_1}\right| = \left|\frac{74 - 80}{7 - 5}\right| = \left|\frac{-6}{2}\right| = 3$

ii) for $\theta = 65^\circ$, $\left(\frac{d\theta}{dt}\right)_{65^\circ} = \left|\frac{y_2 - y_1}{x_2 - x_1}\right| = \left|\frac{60.8 - 66}{4.4 - 2}\right| = \left|\frac{-5.2}{2.2}\right| = 2.3636$

iii) for $\theta = 55^\circ$, $\left(\frac{d\theta}{dt}\right)_{55^\circ} = \left|\frac{y_2 - y_1}{x_2 - x_1}\right| = \left|\frac{56 - 60}{15.4 - 12.4}\right| = \left|\frac{-4}{3}\right| = 1.3333$

iv) for $\theta = 49^\circ$, $\left(\frac{d\theta}{dt}\right)_{49^\circ} = \left|\frac{y_2 - y_1}{x_2 - x_1}\right| = \left|\frac{45.8 - 49}{16 - 12.6}\right| = \left|\frac{-3.2}{3.4}\right| = 0.9411$

v) for $\theta = 44^\circ$, $\left(\frac{d\theta}{dt}\right)_{44^\circ} = \left|\frac{y_2 - y_1}{x_2 - x_1}\right| = \left|\frac{45.4 - 48}{26 - 22.6}\right| = \left|\frac{-2.6}{3.4}\right| = 0.7647$

* Observation table from cooling curve II

for 3rd graph

Obs No.	Temp θ°C	$\frac{d\theta}{dt}$ °C/min	θ − θ₀
01	75°C	3	Here slope is decreasing w.r.to corresponding decreasing temp. Hence, Newton's law of cooling is verified successfully. Ref
02	65°C	2.36	
03	55°C	1.33	
04	49°C	0.94	
05	44°C	0.76	

observe carefully our slope is decreasing. so