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EXPERIMENT - 1

Aim :

Determination of Stefan - Boltzmann constant σ.

Apparatus :

Heater, temperature - indicators, mettallic hemisphere with water - flow, copper - disk as a black body.

Theory :

A black body is an ideal body which absorbs or emits all types of electromagnetic radiation. Acc. to Stefan's law, energy radiated per unit area per unit time is,

$$R = \epsilon \sigma T^4 .$$

ϵ = emmisivity of material

σ = stefan's constant ($5.67 \times 10^{-8}\ W m^{-2} K^{-4}$)

net Heat Transfer, $\frac{\Delta Q}{\Delta t} = \sigma A \left(T_h^4 - T_d^4 \right) = m C_p \frac{dT}{dt}$

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

Procedure :

- Remove the disc from the bottom of the hemisphere and switch on the heater and allow the water to flow through it.
- Allow the hemisphere to reach the steady state and note down the temperature T_1, T_2, T_3.

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- Fit the disc at bottom of hemisphere and note down its rise in temperature with respect to time till steady state is reached.
- A graph is plotted with temperature of disc along Y-axis and time along X-axis.
- Find out the slope dT/dt from the graph.

- For simulator:
- choose desirable values of water temperature, surrounding temperature, mass and radius of disc using sliders.
- Power on wait till T_1, T_2, T_3 reach steady state.
- Plot temperature - time and determine its slope dT/dt, after putting T_4 button and fit the disk.
- Note down T_4 at different intervals of time till it reaches steady state.

Calculation:

Mass of copper disk = 7g = 0.007 Kg.
Radius of the disk = 0.03 m.
Area of disk = 0.002826 m^2
Specific heat of copper = 385 J/Kg.

$$\sigma = \frac{m C_p \frac{dT}{dt}}{A\left(T_h^4 - T_d^4\right)} \quad W m^{-2} K^{-4}.$$

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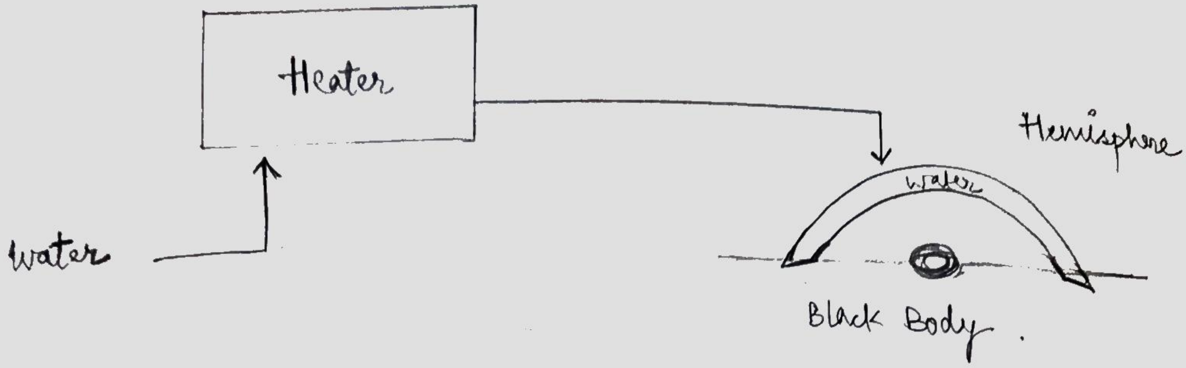


Observation :

①

S.NO.	T (°C)	t (sec)
1	34	30
2	41	60
3	48	90
4	55	120
5	63	150
6	64.33	160

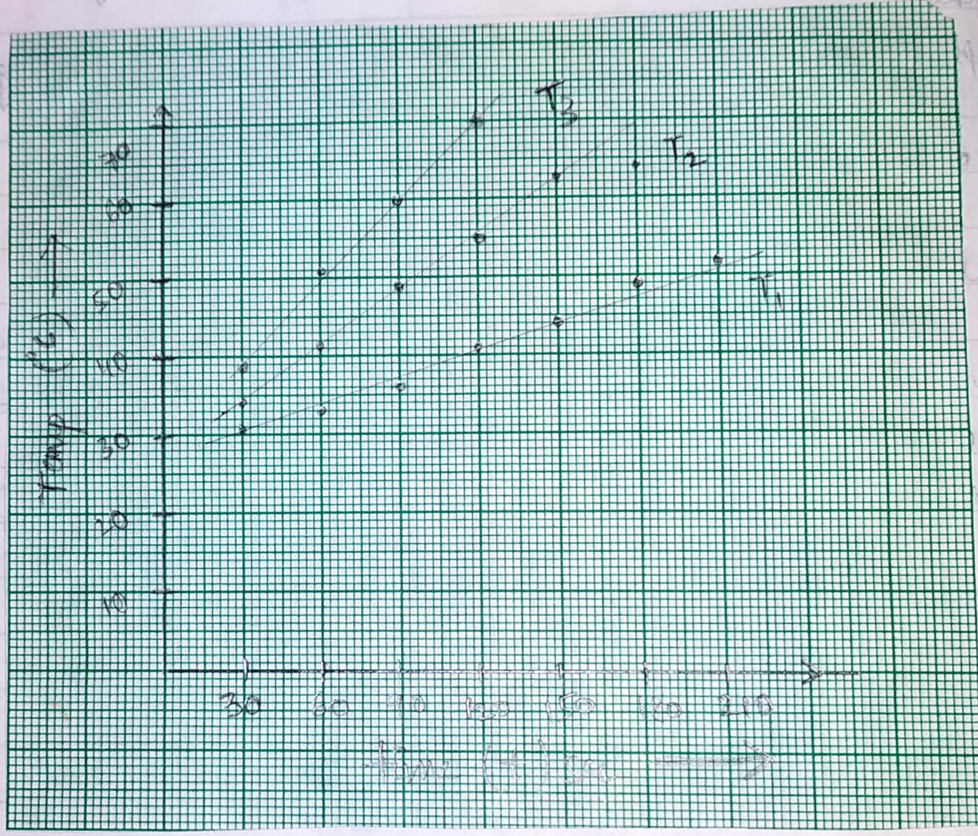
Temp. of hemisphere = 67°
Temp. of disk = 27° .

(2) Temp. of hemisphere = 77°
Temp. of disk = 27°.

S.No.	T (°C)	t (sec)
1.	39	30
2.	51	60
3	60	90
4	76.4	120
5	76.4	150

(3) Temp. of hemisphere = 57°, disk = 27°.

S.No.	T (°C)	t (sec)
1	30.58	30
2	33	60
3	37	90
4	41	120
5	44.8	150
6	48.46	180
7	52.03	210
8	54.42	235



Graph : Temp v/s time

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① $T_h = 330\,K$, $T_d = 300\,K$, $\frac{dT}{dt} = \frac{5}{30}$

$$\sigma_1 = \frac{0.007 \times 385 \times 5}{2826 \times 10^{-6} \times (330^4 - 300^4) \times 30} = 4.228 \times 10^{-8}$$

② $T_h = 340\,K$, $T_d = 300\,K$, $\frac{dT}{dt} = \frac{9}{30}$

$$\sigma_2 = \frac{0.007 \times 385 \times 9}{2826 \times 10^{-6} \times 30\,(340^4 - 300^4)} = 5.435 \times 10^{-8}$$

③ $T_h = 350\,K$, $T_d = 300\,K$, $\frac{dT}{dt} = \frac{12}{30}$

$$\sigma_3 = \frac{0.007 \times 385 \times 12}{2826 \times 10^{-6} \times 30 \times (350^4 - 300^4)} = 5.523 \times 10^{-8}$$

$$\text{Mean } \sigma = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3} = 5.062 \times 10^{-8}.$$

Percent Error :

$$\frac{5.67 \times 10^{-8} - 5.062 \times 10^{-8}}{5.67 \times 10^{-8}} = 10.7\,\%.$$

Result :

Stefan-Boltzmann's constant $\sigma = 5.062 \times 10^{-8}$.

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