To determine the Mechanical Equivalent of Heat by Callender and Barnes Method

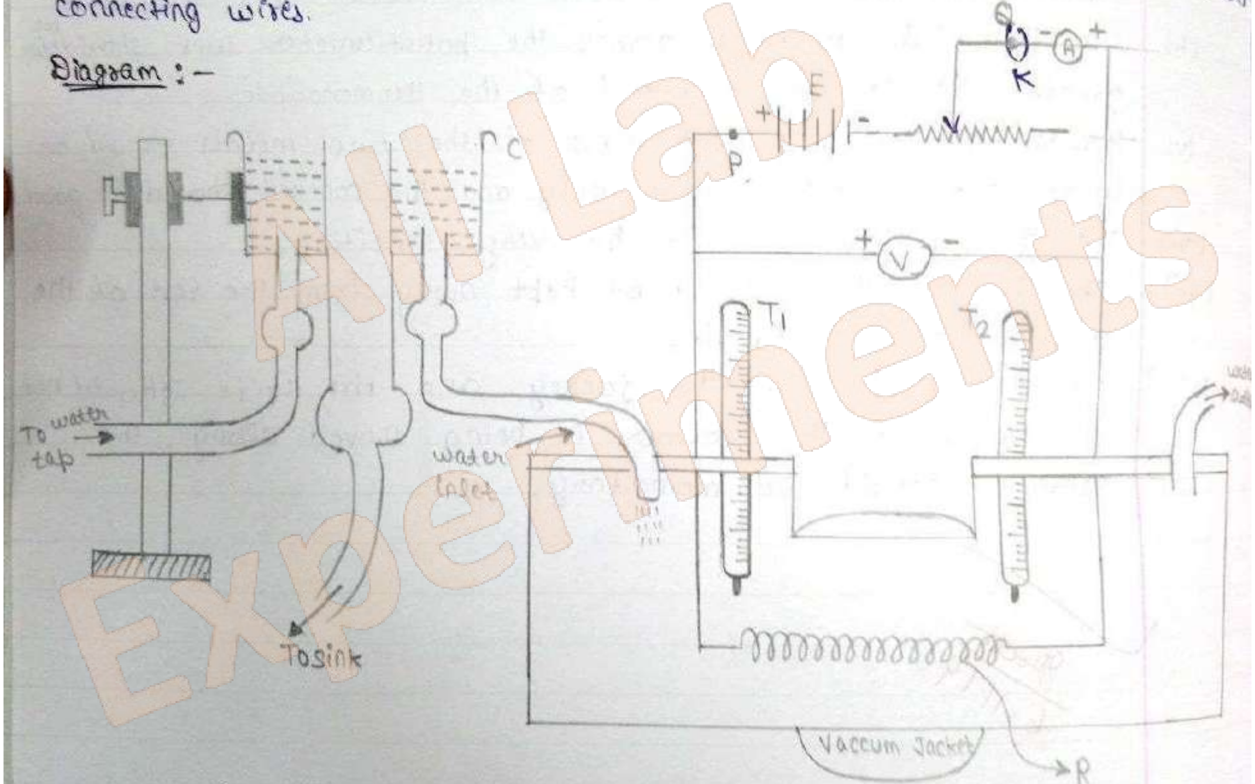
Aim :—

To determine the mechanical equivalent of heat by Callender and Barne's constant flow method.

Apparatus :—

Constant flow calorimeter, a 50V battery (or a.c mains and a step down transformer), a rheostat, an ammeter (0-3amp), a voltmeter (0-50V) a beaker, a stop-watch, 2 1/5th degree thermometer, a key, pinch corks and connecting wires.

Diagram :—



Observation :— Initial Temp. in T_1, = 28°C

Initial Temp. in T_2, = 28°C

(i) Steady State I :

Temp. in T_1, $Q_1 = 28°C$

Temp. in T_2, $Q_2 = 41°C$

} $T_2 = Q_2 - Q_1$

$T_2 = 13°C$

Voltmeter reading, V = 10.5 volts

Ammeter reading, I = 1.4A

Least count of Thermometers = 1/5 °C.

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Theory :-

When the rate of flow of water and the current passing through R are maintained constant, a steady state will be reached and the thermometers T_1 and T_2 will show constant readings. At this stage, the temperatures of every part of apparatus will remain steady. When the thermometers T_1 & T_2 show constant readings say θ_1 and θ_2, the mass of water m flowing in t seconds is measured. S is the specific heat of water flowing between temperatures θ_1 and θ_2, then the amount of heat produced by passage of electric current through the coil is $ms(\theta_2-\theta_1)$

If V and I are the voltmeter and ammeter readings then the amount of energy liberated in time t sec is VIt Joules

The corresponding quantity of heat is $\frac{VIt}{J}$ cals.

Equating the two expression of heat and taking $s = 1\, cal/g\,°C$

$$\frac{VIt}{J} = m(\theta_2-\theta_1)$$

Sr. No	mass of water collected, m (gm)	Time t (sec)	Rate of flow of water m/t (gm/sec)
1.	34	180	0.1888
2.	34	180	0.1888
3.	33	180	0.1833

$m_2 = 33.66$

Steady State II :

Initial Temp. in $T_1 = 28°C$

Initial Temp. in $T_2 = 28°C$

Temp. in T_1, $\theta_1 = 28°C$

Temp. in T_2, $\theta_2 = 40.4°C$

$\} T_1 = \theta_2 - \theta_1$

$T_1 = 12.4°C$

Voltmeter reading, $V_1 = 9.5V$

Ammeter reading, $I_1 = 1.2A$

Least count of thermometer $= 1/5 °C$

Sr. No.	mass of water collected m (gm)	Time t (sec)	Rate of flow of water m/t (gm/sec)
1.	25	180	0.1388
2.	25	180	0.1388
3.	25	180	0.1388

$m_1 = 25$

Similarly,

$$\frac{V_1 I_1 t}{J} = m_1 (\theta_2 - \theta_1)$$

when the temperature difference is same in both cases then

$$\frac{(VI - V_1 I_1)t}{J} = (m - m_1)(\theta_2 - \theta_1)$$

$$J = \frac{(VI - V_1 I_1)t}{(m - m_1)(\theta_2 - \theta_1)} \text{ J/cal}$$

Note :-

If $(\theta_2 - \theta_1)$ is not same in two cases we will use the eq^n

$$J = \frac{(VI - V_1 I_1)t}{m_2 T_2 - m_1 T_1}$$

where T_1 & T_2 are the values of $(\theta_2 - \theta_1)$ and m_1 and m_2 are the mass of water collected in t seconds.

Procedure :-

(i) Connect the circuit as shown in figure (i)

(ii) Change the current through rheostat (means move the rheostat) and note down the current and voltage through ammeter and voltmeter.

(iii) The thermometer Ist (water supplies from tank directly) is shown room temp and then water flows from heater and heater takes times to heat up the water flows through it.

(iv) The thermometer 2nd (which connect directly through thermometer Ist) takes time to give rise up.

(v) After increase the temp in thermometer 2nd we got the lculation :—

$$J = \frac{(VI - V_1 I_1)t}{m_2 T_2 - m_1 T_1}$$

$$J = \frac{(10.5 \times 1.4 - 9.5 \times 1.2) \times 180}{(33.66 \times 13 - 25 \times 12.4)}$$

$$J = \frac{(14.7 - 11.4) \times 180}{(437.58 - 310)} = \frac{594}{127.58} = 4.656 \text{ J/cal}$$

Standard Value = 4.185 J/cal

$$\% \text{ Error} = \left| \frac{4.185 - 4.656}{4.185} \right| \times 100 = 11\,\%$$

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Steady state and after this we arrest the experiment.

(vi) At steady state, note down the temp. in T_1 and T_2 thermo-meters.

(vii) Collect the water in measuring beaker 3 times and by the we can calculate rate of flow of water.

(viii) After this, change the rate of flow, by cork of water and then increase the current through rheostat and got steady state through thermometer first and 2nd.

(ix) Repeat the above procedure for case II means the case in which we increase the current.

(x) Note down the readings very carefully.

Result :—

The value of mechanical equivalent of heat, J is

$J = 4.656$ J/cal.

Standard value $= 4.185$ J/cal.

% Error $= 11$ %

Precaution and Sources of Error :—

(i) Water should be passed through the tube before passing the current.

(ii) There should be no air bubble in the tube.

(iii) When alternating current is used a.c voltmeter and ammeter should be used.

(iv) A constant level water tank should be used for maintaining a constant rate of flow.