B.Sc Part I (Physics Hons)
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Ques:- State and prove Stefan's - Boltzmann law. How it has experimentally verified.? Give an account of method for the determination of Stefan's constant?

Ans:- Stefan's law:-

As we know, the rate of emission of radiation per unit area per sec by a Black body is directly proportional to the fourth power of the absolute temperature of the Black body such that

$$E \propto T^4 \Rightarrow E = \sigma T^4$$

Here σ = Stefan's constant having its value is $5.67 \times 10^{-8} \, W m^{-2}$

Stefan - Boltzmann law :-

As we know $E = \sigma(T^4 - T_0^4)$. That is if a black body at ~~absolute term~~ absolute temp. T be surrounded another black body at absolute temp T_0, then the amount of energy E radiated per unit area per second by the former is directly proportional to $(T^4 - T_0^4)$

Deduction :-

The black body radiation behaves like a gas, it exerts pressure and possesses. Hence thermodynamic can be applied to black body radiation just as in the case

For deducing this law, we consider radi in a black body chamber and try to apply thermodynami laws to the radiation.

Let u denotes the energy density of radiation the enclosure, V its total volume and P the pressure of radiation u and P are simply functions of the absolute temp T. We have the total energy (U) of radiation = uV, then

First thermodynamic Relation

$$\left(\frac{dQ}{dV}\right)_T = T\left(\frac{dP}{dT}\right)_V$$

~~For~~ from First law of thermodynamics

$$dQ = dU + PdV$$

Hence

$$\frac{1}{T}\left[\frac{dU + PdV}{dV}\right]_T = \left[\frac{dP}{dT}\right]_V$$

$$\Rightarrow \frac{1}{T}\left[\frac{dU}{dV} + P\right]_T = \left(\frac{dP}{dT}\right)_V$$

$$\Rightarrow \left(\frac{dU}{dV}\right)_T = T\left(\frac{dP}{dT}\right)_V - P$$

Since the radiation is diffuse

$$\frac{dW}{dV} = u \text{ and } P = \frac{u}{3}$$

or $u = \frac{T}{3} \cdot \frac{du}{dT} - \frac{u}{3}$ or $\frac{T}{3} \cdot \frac{du}{dT} = \frac{4u}{3}$

or, $\frac{du}{u} = 4\frac{dT}{T}$ or $\log u = 4 \log T + K$

$u = \sigma T^4$ This is Stefan's law.

Next, let us consider a black body A at temp. T surrounded by another black body B at temperature T_0. Let ΔS be an elementary area of A.

Rate of emission by $\Delta S = \sigma T^4 \Delta S$

Rate of emission by $A = \Sigma \sigma T^4 \Delta S$

Rate of emission by $A = \Sigma \sigma T_0^4 \Delta S$

$\therefore$ Rate of loss of heat by $A = \sigma (T^4 - T_0^4) \Sigma \Delta S$

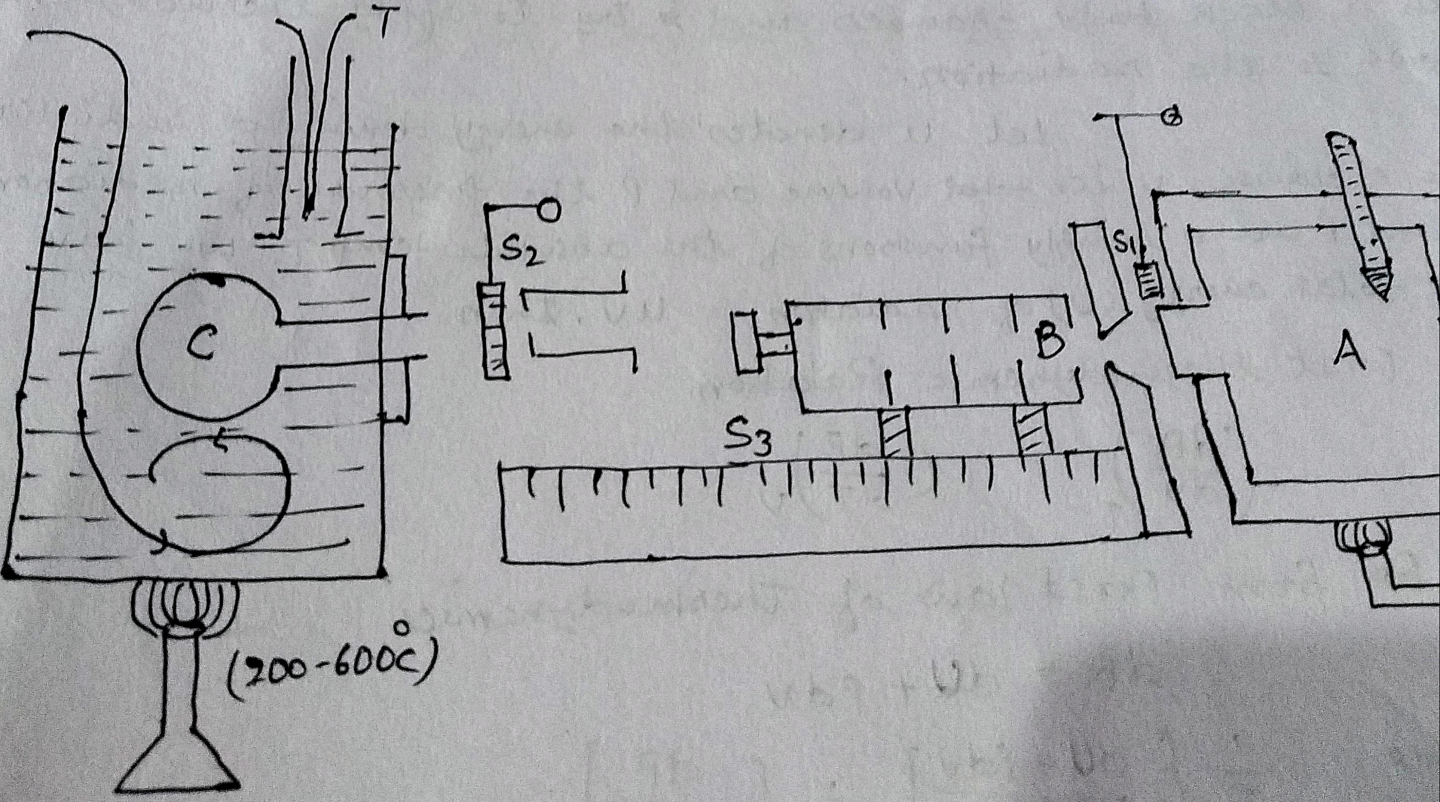
Rate of loss of heat from unit area

$$E = \frac{\sigma (T^4 - T_0^4) \Sigma \Delta S}{\Sigma \Delta S} = \sigma (T^4 - T_0^4)$$

This is Stefan's Boltzmann law.

Verification of Stefan - Boltzman law :→

This can be done by Lummer and Pringsheim's experiment



To verify this law the black bo

maintained at any desired temperature. The temp. is measured by a thermocouple thermometer. A is another chamber sourrounded by boiling water. This serve as a standard source of radiation for calibrating the bolometer, detector of radiation B. The carrier of the bolometer can be moved and its position can be read off on a scale attached, S_1, S_2, S_3 are shutters so that radiation can be stopped or allowed to fall at will.

The chamber C is heated up to the desired temp. and kept maintaned, then the shutter S_2 is raised to allow radiation to fall on the bolometer and the maximum deflection ~~m~~ in the galvanometer noted. The deflection due to the intensity of radiation at a distance 0.63 from the standard source A is taken as an ~~or~~ arbitrary unit and all observations are reduced to this unit. If 'd' is the deflection to the galvanometer, in terms of this standard deflection. T be the absolute temp of the chamber C, To the temperateere of the shutter protecting the bolometer, then

$$d = \alpha (T^4 - T_0^4)$$ from Stefan-Boltzmann Law.

For difference in temperatures of the chamber, α is found to be constant. The truth of the law is attained.