Lecture-19

30/9/2023.

Quantum Physics

* Acc. to classical Physics ⇒

§ A particle is charaterized by an energy E & momentum $\overline{p}$.

§ Wave is charaterized by an amplitude & a wave vector $\overline{k}$.

§ These rigid concepts of C.M. led to the failure in explaining a no. of microscopic phenomina such as-

Blackbody radiation.

Photo electric effect.

Compton effect etc.

* It turn out that these phenomina could be explained by introducing particle aspect of radiation.

Blackbody Radiation ⇒

An ideal blackbody absorbs all radiation incident upon it regadless of freqency.

⇒ All blackbodies behave identically

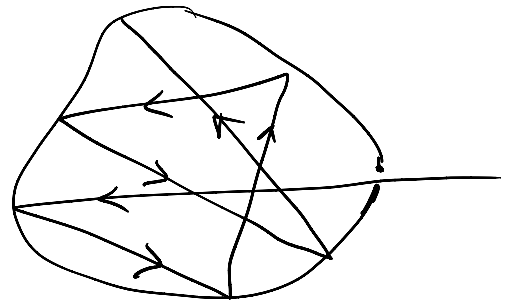
* When an object is heated, it radiates EM energy as a result of thermal agaitation of the electrons in it's surface.

* The intensity of this radiation depends on it's freqency f on the tem.

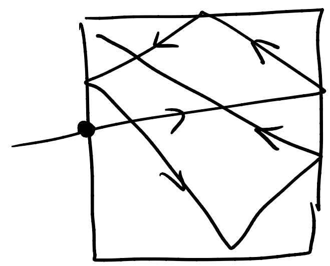
Ex:- Iron bar ⇒ dull red → bright organge → Purple/blue.

In lab, a blackbody can be approximated by a hollow object with a very small hole. Any radiation striking the hole enters the cavity & it will trapped by reflection back & forth until it absorbed.

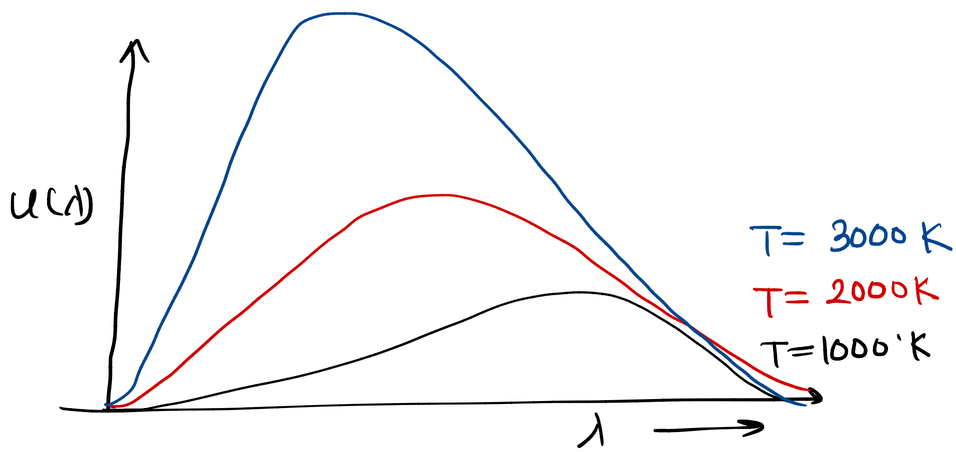
Let say the cavity walls are constantly emitting & absorbing radiation & we are interested in the properties of this radiation.

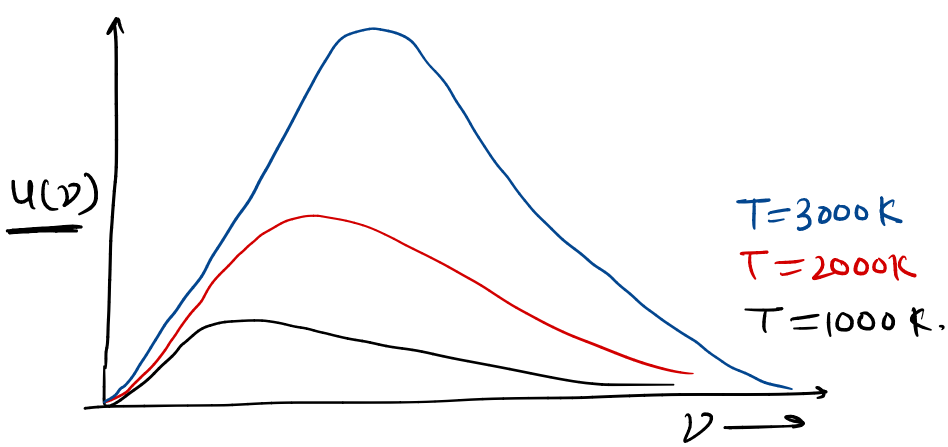


* Assume that the walls of the cavity are uniformly heated at temp T. Then the walls will emit thermal radiations which will fill the cavity.



Experimental observation :→





$u(\nu) \Rightarrow$ Energy per unit time per unit area at temp T.

$u(\nu)d\nu \rightarrow$ " " " " b/w frequency ν & $\nu+d\nu$.

* Radiancy $E_T = \int_0^\infty u(\nu)\, d\nu$.

$$\boxed{E = a\sigma T^4}$$

$a \rightarrow \leq 1$ for perfect blackbody $=1$

§ Stefan's law [Empirical eqn].

$\sigma = 5.67 \times 10^{-8}\ W/m^2\text{-}K^4$

§ Wien's displacement law $\Rightarrow$

$$\boxed{\lambda_{peak} \propto \frac{1}{T}}$$

proportionaly const $= 2.9 \times 10^{-3}$ m K.

Wien's energy density distribution $\Rightarrow$

Using thermodynamic argument

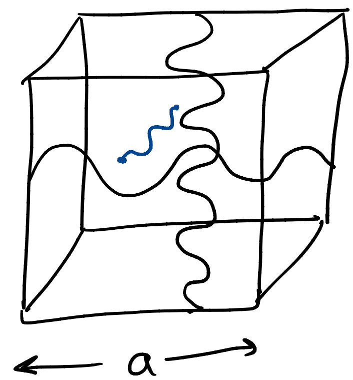
$u(\nu, T) = A\nu^3 e^{-\beta\nu/T}$

A & β are two parameters that can be adjusted to fit the data.

$u(\nu,T) \Rightarrow$ Energy per unit volume per unit frequency.

$\Rightarrow$ fits the high frequency data but fails at low frequency.

Rayleigh's energy density distribution :-



* The radiation inside the cavity will be in the form of standing wave.

* Using geometrical argument, He counted the no. of such standing wave in the frequency range ν to $\nu + d\nu$.

$$a = \frac{n\lambda}{2}$$

$$n_x = \frac{2a}{\lambda_x}$$

$$n_y = \frac{2a}{\lambda_y}$$

$$n_z = \frac{2a}{\lambda_z}$$

where n_x, n_y, n_z are 1, 2, 3 - - -

Therefore -

$$n_x^2 + n_y^2 + n_z^2 = \left(\frac{a}{\pi}\right)^2 K^2$$

where $K^2 = k_x^2 + k_y^2 + k_z^2$.

$$\therefore \quad n_x^2 + n_y^2 + n_z^2 = \left(\frac{2a\nu}{c}\right)^2$$

This is the eq^n of sphere with radius $\frac{2a\nu}{c}$.