D-I(5)

Q:→ State and prove Kirchoff's law of radiation. Give its importance.

Soln:→ **Kirchoff's law:-**

The ratio of the emissive power of the absorption power of radiation of a given wavelength is the same for all bodies at the same temperature and is equal to the emissive power of a perfectly black body at that temperature.

Let us suppose that a body is placed in a uniformly heated enclosure at a constant temperature. Let the radiant energy $d\theta$ between the wavelength λ and $\lambda + d\lambda$ be the incident on a surface of unit area per second. Let a_λ be the absorptive power of the body for the wavelength λ. Then amount of energy $a_\lambda d\theta$ will be absorbed per second by the surface of unit area of the body. The remaining $d\theta - a_\lambda d\theta$ of the incident energy will be reflected or transmitted.

Let e_λ be the emissive power of the body at wavelength λ. Then energy $e_\lambda d\lambda$ between the wavelength λ and $\lambda + d\lambda$

will be emitted per second by unit area of the surface of the body.

Thus the total energy sent out by unit area of the body per second is $(d\theta - a_\lambda d\theta) + e_\lambda d\lambda$.

Since the presence of the body does not affect the quantity or quality radiation stream in the enclosure, therefore the energy sent out by unit area of the body per second should be equal to the energy received and hence,

$$(1 - a_\lambda)\, d\theta + \theta_\lambda d\lambda = d\theta$$

$$\Rightarrow d\theta - a_\lambda d\theta + e_\lambda d\lambda = d\theta$$

$$\therefore a_\lambda d\theta = e_\lambda d\lambda \quad \text{——————} \quad (1)$$

For a perfectly black body $a_\lambda = 1$ and $e_\lambda = E_\lambda$ = emissive power of the black body.

$$\therefore E_\lambda d\lambda = d\theta$$

$$\Rightarrow a_\lambda E_\lambda d\lambda = e_\lambda d\lambda \quad (\text{from eqn. } 1)$$

$$\therefore E_\lambda = \frac{e_\lambda}{a_\lambda}$$

Since E_λ is constant at a given temperature.

$$\frac{e_\lambda}{a_\lambda} = E_\lambda = \text{const.}$$

for all substances at the same temperature. Thus we see that the ratio of emissive power to the absorptive power of a body for a given temperature and wavelength is equal to the emissive power of a perfectly black body and is therefore, const. This is Kirchoff's law.

Importance of Kirchoff's law :-

When a polished metal sphere having black spot in its side is heated to a very high temperature the black spot which absorbs light more strongly than the polished surface at ordinary temperature emits light more strongly at high temperature