- SEMESTER –II(GE)
- PAPER : GE2
- TOPICS: BLACK BODY RADIATION

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6.1.1 Definition of a black body

A black body is an ideal body which allows the whole of the incident radiation to pass into itself (without reflecting the energy) and absorbs within itself this whole incident radiation (without passing on the energy). This property is valid for radiation corresponding to all wavelengths and to all angles of incidence. Therefore, the black body is an ideal absorber of incident radiation. All other qualitative characteristics determining the behaviour of a black body follow from this definition (see, for example, Siegel and Howell, 1972; Ozisik, 1973).

Black body radiation:

If the temperature of a closed cavity changes, then, accordingly, the temperature of a black body enclosed inside it should also change and become equal to the new temperature of a cavity (i.e. a fully insulated system should tend to thermodynamic equilibrium). The system will again become isothermal, and the energy of radiation absorbed by a black body will again be equal to the energy of radiation emitted by it, but it will slightly differ in magnitude from the energy corresponding to the former temperature. Since, by definition, the body absorbs (and, hence, emits) the maximum radiation corresponding to the given temperature, the characteristics of an enclosing system have no influence on the emission properties of a black body. Therefore, the total radiation energy of a black body is a function of its temperature only.

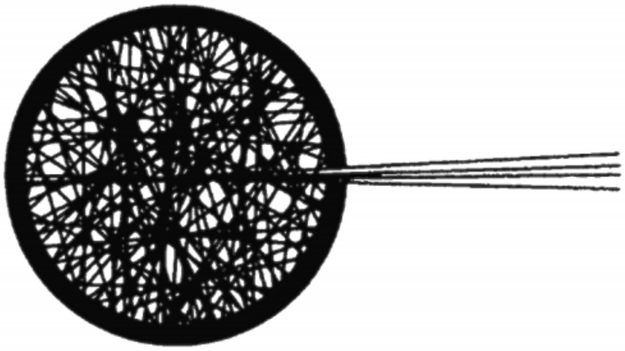


Figure 6.1. Classic experimental model of black-body source.

heated bodies depends only on their temperature and does not depend on the chemical composition of the emitting substance. Kirchhoff considered theoretically the radiation inside a closed cavity in a rigid body, whose walls possess some particular temperature. In such a cavity the walls emit as much energy as they absorb. It was found that under these conditions the energy distribution in the radiation spectrum does not depend on the material the walls are made of. Such a radiation was called ‘absolutely (or ideally) black’.

Emissive power : (e_λ)

Emissive power is the energy of thermal radiation emitted in all directions per unit timeper unit area of a surface at any given temperature.

When heat is incident on the surface of the body some of the heat is absorbed while other is reflected. **Emissive power** : " the **energy** of thermal radiation emitted in all directions per unit time from each unit area of a surface at any given temperature"

Absorptive power: (a_λ)

The **absorptive power of a body** (or a surface) is defined as the ratio of the energy absorbed in a given time (or in a certain time) to the radiant energy incident on it at the same instant of time. Therefore **absorptive power**, a = Amount of energy absorbed / Amount of energy incident.

Kirchhoff 's radiation law :

The spectral absorptivity, αλ, is the fraction of incident radiation absorbed at wavelength λ. A black body is a material for which αλ = 1 for all λ. The spectral emissive power, eλdλ, is the power emitted per unit area with wavelengths between λ and λ + dλ.

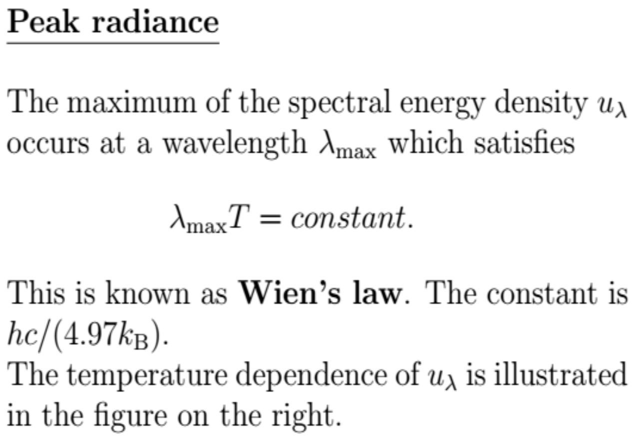
Kirchhoff 's radiation law states that the ratio of emissive power to absorptive power eλ/αλ = f(λ, T), a universal function of wavelength and temperature, independent of the nature or shape of the cavity. This law accounts for the fact that for a given wavelength of radiation, good absorbers are also good emitters.

What Was Observed: Two Laws

The first quantitative conjecture based on experimental observation of hole radiation was:
Stefan's Law (1879): the ***total*** power *P* radiated from one square meter of black surface at temperature *T* goes as the *fourth power* of the absolute temperature:
$P = \sigma T^4$, $\sigma = 5.67\ 10$ watts/sq.m./K . -
Five years later, in 1884, Boltzmann derived this T^4 behavior from theory: he applied classical thermodynamic reasoning to a box filled with electromagnetic radiation, using Maxwell's equations to relate pressure to energy density. (The tiny amount of energy coming out of the hole would of course have the same temperature dependence as the radiation intensity inside.)

Wien's Law. **Wien's Law** tells us that objects of different temperature emit spectra that peak at different wavelengths. Hotter objects emit most of their radiation at shorter wavelengths; hence they will appear to be bluer

As the oven temperature varies, so does the frequency at which the emitted radiation is most intense. In fact, that frequency is directly proportional to the absolute temperature:
$f_{max} \propto .T.$

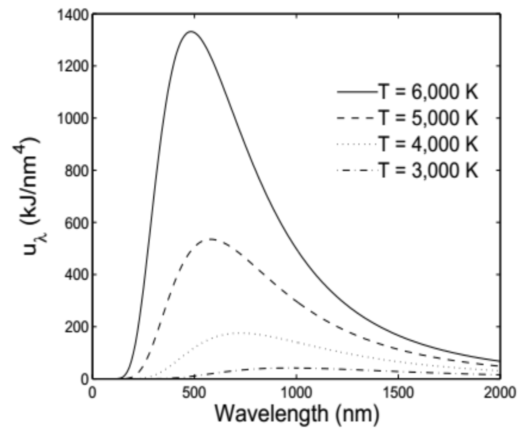


Peak radiance

The maximum of the spectral energy density u_λ occurs at a wavelength $\lambda_{\max}$ which satisfies

$$\lambda_{\max} T = constant.$$

This is known as **Wien's law**. The constant is $hc/(4.97k_B)$.
The temperature dependence of u_λ is illustrated in the figure on the right.



References :

1. Thermal physics book by A.B GUPTA