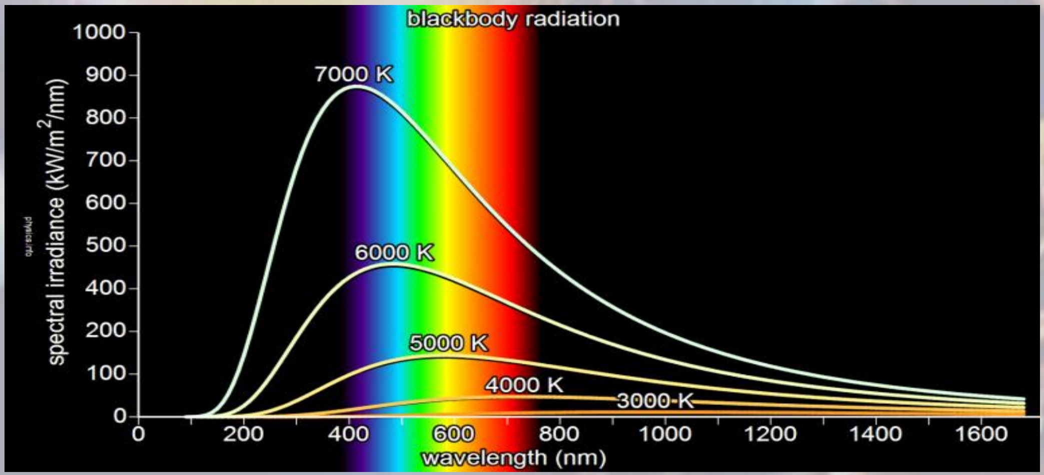
Physics- II Semester

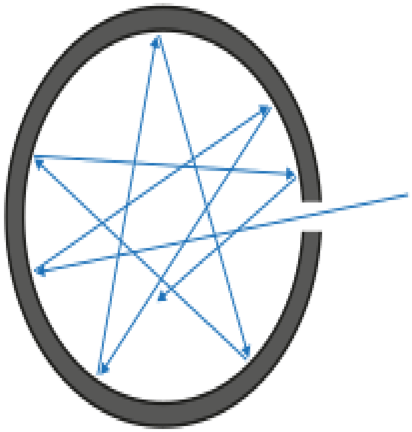
PAPER:HEAT, THERMODYNAMICS AND SOUND
TOPIC:RADIATION(part I)

11-Apr-2020



Shreedevi N D

Blackbody



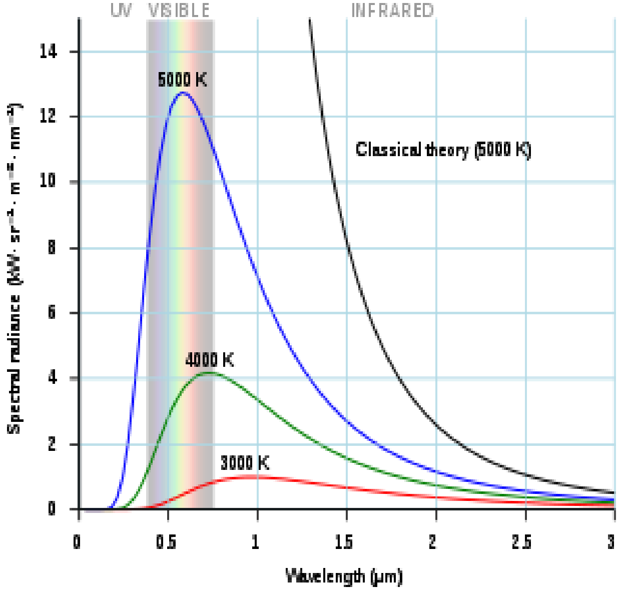
An ideal blackbody is the one that absorbs radiation of all wavelengths incident on it. The name "blackbody" is given because it is a perfect absorber of radiation in all frequencies and it is a perfect emitter of radiation.

Blackbody in thermal equilibrium at a fixed temperature T, emits radiation at a faster rate than any other body at the same temperature and it emits radiation of all wavelengths.

A blackbody may be obtained by making a small hole in a cavity (hollow object). Any radiation entering the cavity through a hole is completely absorbed due to multiple reflection and absorption at the inner wall of the cavity and hence do not leave the cavity through the hole. The cavity walls are constantly emitting and absorbing radiation.

Distribution of energy in blackbody spectrum

spectral distribution of a black body



O Lummer

E Pringshiem

When the cavity is heated, the walls of the cavity emit radiation and the radiation emerging from the hole of the cavity is called blackbody radiation.

The energy density ψ_λ is the energy of radiation in unit volume of the cavity per unit wavelength interval.

The graph of ψ_λ versus λ represents the spectral distribution of a black body.

Features of blackbody spectrum

- At a given temperature, the energy is not uniformly distributed in the radiation spectrum of the body.

- The energy density ψ_{λ} increases with an increase in wavelength and at a particular wavelength λ_{max}, it has a maximum value. With a further increase in wavelength, ψ_{λ} decreases.

- For all wavelengths, an increase in temperature causes an increase in energy emission.

- At a given temperature T, radiation of a particular wavelength λ_{max} is emitted with maximum energy density ψ_{λ}.

Features of blackbody spectrum

- As temperature of blackbody T increases, λ shifts to the shorter wavelength

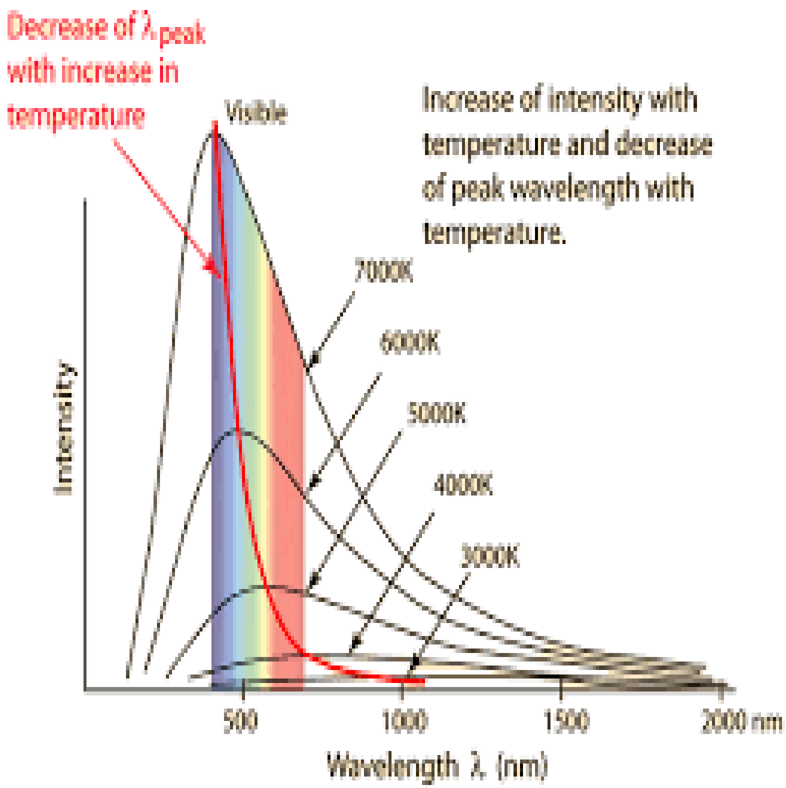
- The product $\lambda_{max} \times T =$ constant. The value of the constant is about 2.9×10^{-3} m K

- The area under each curve represents the total energy (E) radiated over all wavelengths at a particular temperature.

- It is found that area is directly proportional to the fourth power of kelvin temperature T. Thus

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

Wien's displacement law

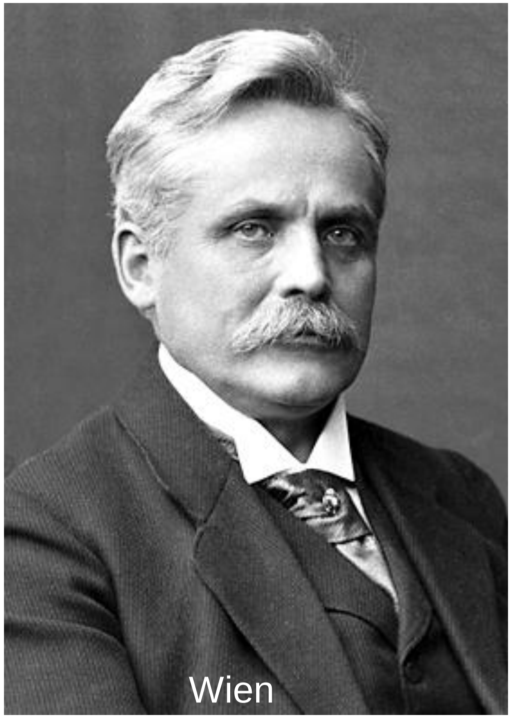


Wien observed that the wavelength of radiation (λ_{max}) emitted with maximum energy is inversely proportional to the temperature T of the blackbody. (Wien's displacement law)

Hence the product $\lambda_{max} \times T$ = constant. The value of the constant was found experimentally to be 2.898×10^{-3} m K

Hotter objects emit most of their radiation at shorter wavelengths; hence they will appear to be blue.

Wien's distribution law (Wien's approximation)



Wien obtained a theoretical formula for ψ_λ in terms of λ by making special assumptions regarding the process of emission and absorption of radiation by a surface.

Wien's formula is $\psi_\lambda = c_1\lambda^{-5}e^{-\frac{c_2}{\lambda T}}$, where c_1 and c_2 are constants.

This formula is in agreement with experiment of Lummer & Pringshiem in shorter wavelength but fails for longer wavelength.

In 1911, Wien was awarded the Nobel Prize in Physics for his discoveries regarding the "laws governing the radiation of heat".

Rayleigh-Jeans law

Rayleigh

Jeans

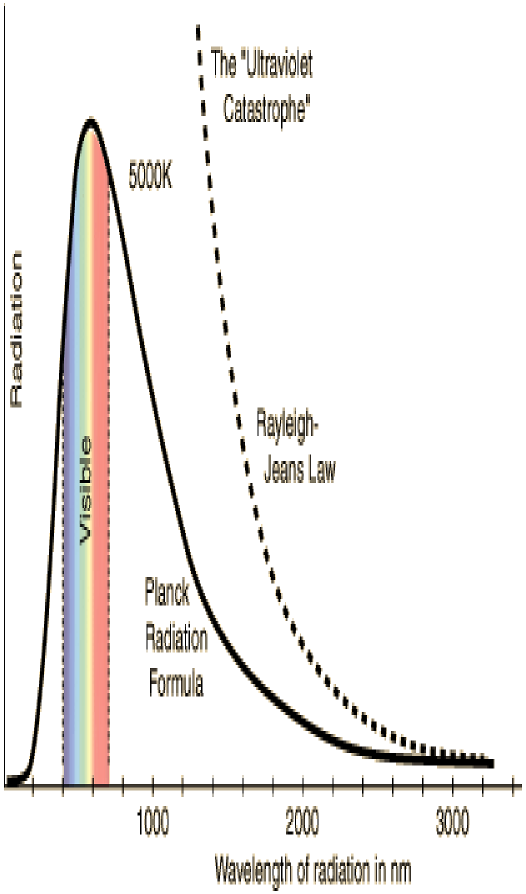
- Rayleigh and Jeans proposed the following theoretical formula for law ψ_λ by applying the principle of equipartition of energy.

- $\psi_\lambda = \frac{8\pi KT}{\lambda^4}$, where K is Boltzmann constant and T is the temperature of blackbody.

- This formula may be used to accurately describe the long wavelength spectrum of blackbody radiation but fails to describe the short wavelength spectrum.

Rayleigh was awarded the Copley, Royal, and Rumford Medals of the Royal Society, and the Nobel Prize for 1904.

Ultraviolet catastrophe



- According to Rayleigh-Jeans formula, as λ decreases towards shorter wavelength ultraviolet region, ψ_λ should increase
- in the limit of very small wavelength ($\lambda \longrightarrow 0$), $\psi_\lambda \rightarrow \infty$.
- But experimentally as $\lambda \rightarrow 0, \psi_\lambda \rightarrow 0$.
- This wide discrepancy between theoretical values from Rayleigh – Jeans formula and experimental results in the ultraviolet region is referred to as **ultraviolet catastrophe**.

Planck's quantum theory of radiation

- According to Planck, the walls of the cavity of a blackbody at temperature T contain atomic oscillators vibrating with all frequencies.

- Planck assumed that an oscillator vibrating with frequency ν can vibrate only in states of discrete energies 0,hν, 2hν….. nhν where n is an integer and h is Planck's constant.

- He suggested that energy is radiated or absorbed by the blackbody in discrete packets, called quanta rather than as a continuous wave. Each quantum is associated with radiation of a single frequency.

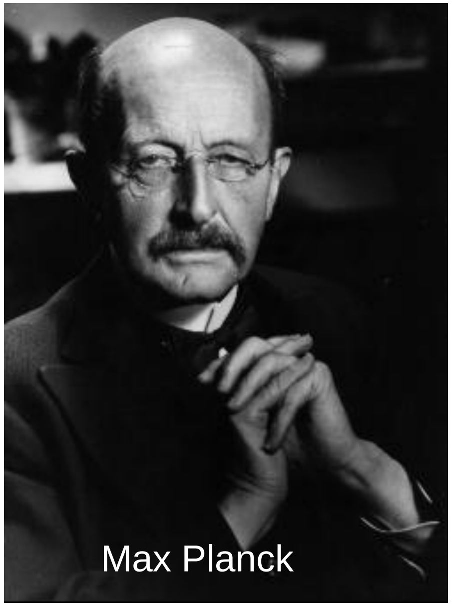
- The energy E of each quantum is proportional to the frequency ν, and

  E = nhν, Here h is Plank's constant. Its value is 6.63×10^{-34} Js.

Planck's law of radiation

- Based on the quantum theory of radiation, Planck arrived at the law of radiation which gives the variation of ψ_λ with wavelength λ.

- Planck's law of radiation is $\psi_\lambda = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{\left(\frac{hc}{\lambda kT}\right)} - 1}$



Max Planck received the Nobel prize in physics in 1918 for his discovery of energy quanta.

Scientific discovery and scientific knowledge have been achieved only by those who have gone in pursuit of it without any practical purpose whatsoever in view - Max Planck

THANK YOU