BLACK BODY RADIATION

B.Sc. Physics (Hons.) – Semester VI
Paper XI (Theory)

Prepared by:
Dr. Usha Kumari
Assistant Professor, Physics Department
Maharaja College, Ara

1. Introduction

Black body radiation refers to the electromagnetic radiation emitted by an ideal black body when it is in thermal equilibrium. The study of black body radiation played a vital role in the development of quantum theory.

2. Black Body

A black body is an ideal body which absorbs all incident radiation irrespective of wavelength and direction and emits maximum possible radiation at a given temperature. A cavity with a small hole acts as a practical example of a black body.

3. Black Body Radiation

The radiation emitted by a black body in thermal equilibrium is called black body radiation. The nature of radiation depends only on temperature and is independent of the material of the body.

4. Experimental Distribution of Energy

Experimental observations show that the intensity of radiation varies with wavelength. For a fixed temperature, the intensity first increases, reaches a maximum value, and then decreases. With increase in temperature, the peak shifts towards shorter wavelengths.

5. Rayleigh–Jeans Law

According to classical theory, the energy density of radiation is given by:
$u(\lambda)d\lambda = (8\pi kT / \lambda\blacksquare)\ d\lambda$
This law agrees with experimental results at longer wavelengths but fails at shorter wavelengths, leading to the ultraviolet catastrophe.

6. Failure of Classical Theory

Classical theory predicts infinite energy at short wavelengths, which is not observed experimentally. This failure indicated the inadequacy of classical physics in explaining black body radiation.

7. Planck’s Quantum Hypothesis

Max Planck proposed that energy is not emitted or absorbed continuously but in discrete packets called quanta. The energy of each quantum is given by:
$E = h\nu$

8. Planck’s Radiation Law (Complete Expression)

Planck derived the radiation law as:
$u(\lambda)d\lambda = (8\pi hc / \lambda\blacksquare)\ [1 / (e^{(hc/\lambda kT)} - 1)]\ d\lambda$
This law successfully explains the black body radiation spectrum over the entire range of wavelengths.

9. Wien’s Displacement Law

The wavelength corresponding to maximum intensity is inversely proportional to absolute temperature:
$\lambda_{max} T = 2.898 \times 10^{-3}$ mK

10. Stefan–Boltzmann Law

The total energy radiated per unit area per unit time by a black body is proportional to the fourth power of its absolute temperature:
$E = \sigma T^4$

11. Diagram (For Examination)

Figure: A graph between intensity of radiation and wavelength. Different curves correspond to different temperatures. As temperature increases, the peak of the curve shifts towards shorter wavelength and the area under the curve increases.

12. Conclusion

Black body radiation marks the failure of classical physics and the beginning of quantum mechanics. Planck’s radiation law provided a correct theoretical explanation and laid the foundation of modern physics.