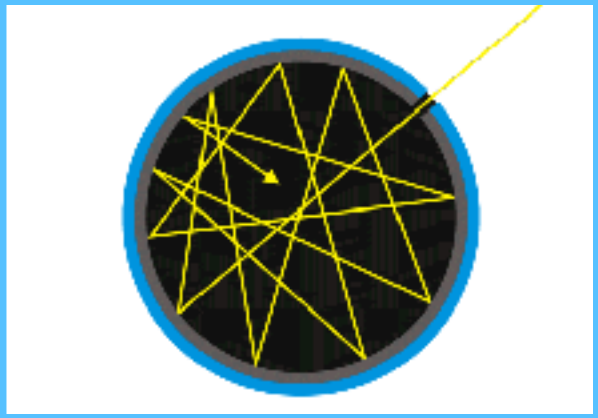
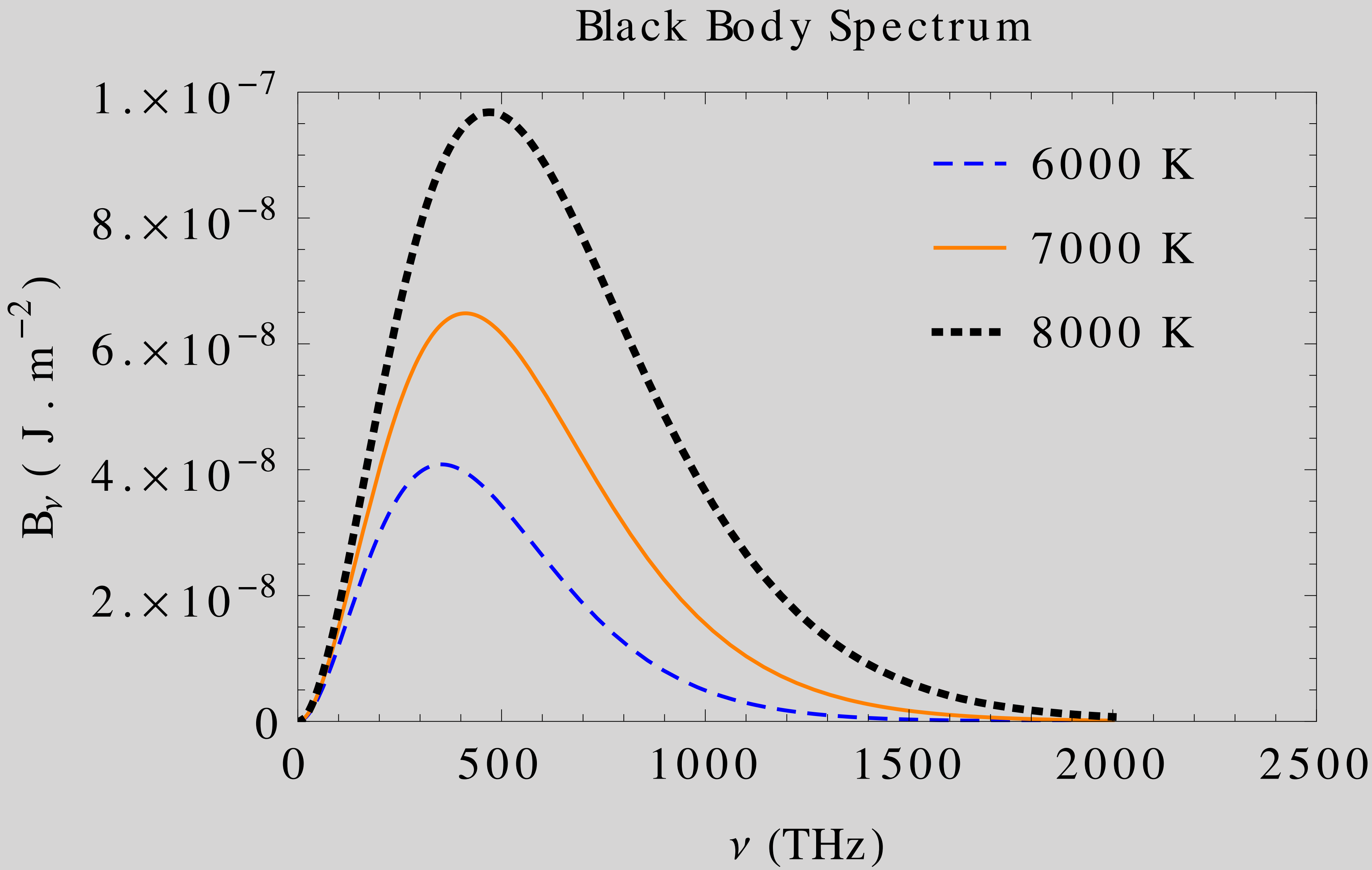
Quantum Mechanics

Old Quantum Theory



Black Body

- Black bodies are ideal objects that absorb radiation of all wavelengths falling on it.
- Generally, detailed form of the spectrum of the thermal radiation emitted by a hot body depends somewhat upon the composition of the body.
- Black bodies exhibit a uniform character of thermal radiation.



The frequency of most intense radiation at a given temperature shifts toward higher value as one elevates the temperature

$$Wein's Law : \lambda_m T = const$$

Theory of Cavity Radiation

- Rayleigh-Jeans assumed the cavity is filled with standing waves generated by the reflected electromagnetic waves from the walls. The nodes of the standing waves are at the boundary walls of the cavity. The thermal agitation on a molecule would cause the electrons to oscillate and emit EM radiation.

The energy per unit volume in the frequency interval ν *to* $\nu + d\nu$ of the blackbody spectrum of a cavity at temperature T is just the product of the average energy per standing wave times the number of standing waves in the frequency interval, divided by the volume of the cavity.

$$\rho_T(\nu)d\nu = \frac{8\pi K_B T}{c^3}\nu^2 d\nu$$

Boltzmann's constant $K_B = 1.38 \times 10^{-23} J/K$

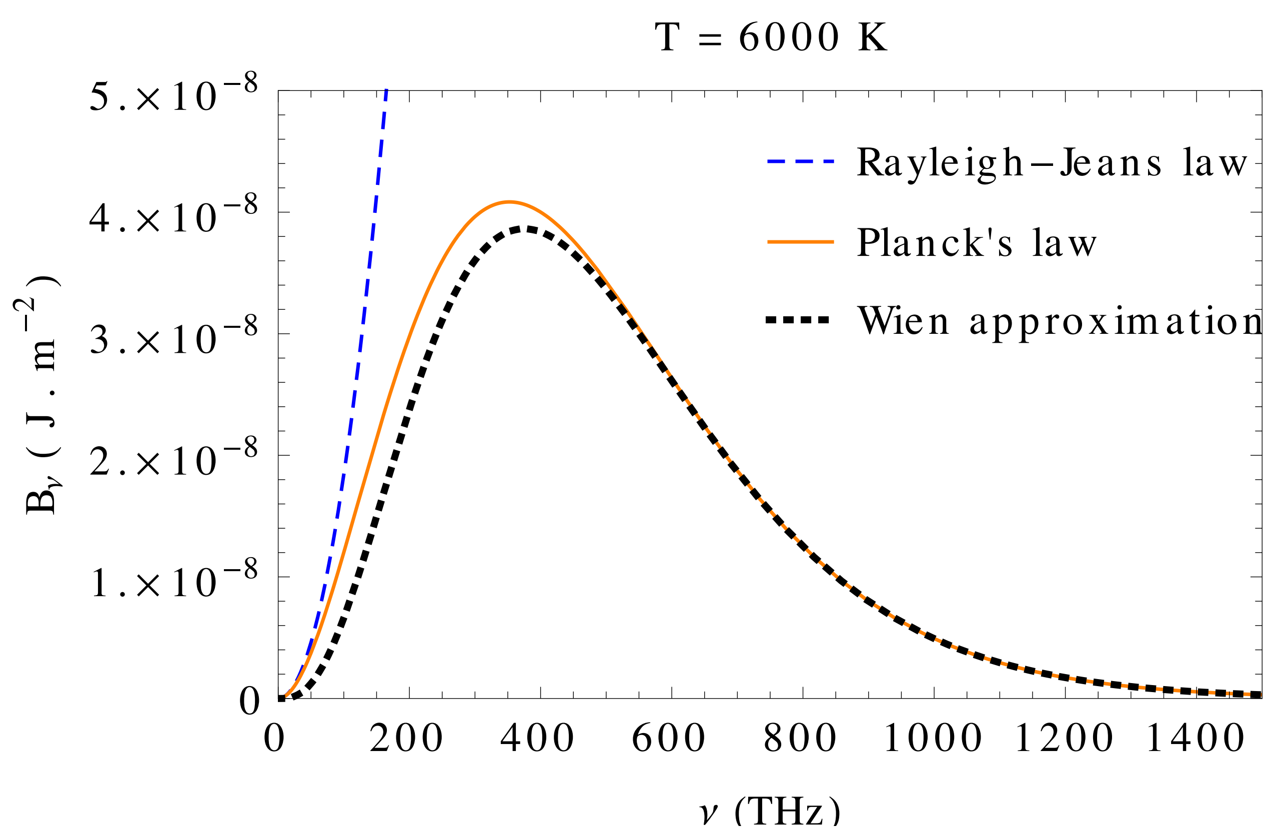
Law of Equipartition of Energy: $\bar{E} = K_B T$

Ultra Violet Catastrophe

- RJ law fails to explain the black body spectrum in the high frequency regime.

- RJ formula explains the low frequency behaviour of the spectrum well.

Energy density tends to ∞ at high frequency



Comparing three laws

Planck's Hypothesis

- Planck (1900) realised the classical law of equipartition of energy would not hold for black bodies.
- A cut-off for the energy density is required at high frequency
- He assumed the energy of the electromagnetic standing waves, oscillating sinusoidally in time, as a discrete instead of a continuous quantity.
- $$\Delta E \propto \nu$$

$$E = h\nu$$

Planck's constant $h = 6.63 \times 10^{-34}\ Joul - sec$

Planck's Spectra

Average Energy: $\bar{E} = \frac{\sum_{n=0}^{\infty} nh\nu e^{\frac{-nh\nu}{K_B T}}}{\sum_{n=0}^{\infty} e^{\frac{-nh\nu}{K_B T}}}$

$$\bar{E} = \frac{h\nu}{e^{\frac{h\nu}{K_B T}} - 1}$$

Planck's Distribution: $\rho_T(\nu)d\nu = \frac{8\pi\nu^2}{c^3}\frac{h\nu}{e^{\frac{h\nu}{K_B T}}-1}d\nu$

Photoelectric Effect

- For any metallic surface, the fastest ejected photoelectron's kinetic energy is independent of the intensity of the falling light.
- Rather it depends on the frequency of the falling light.
- Einstein postulated (1905) the energy of an incident photon (bundle of energy) is also discrete and exactly equal to $h\nu$
- Maximum energy of emitted photo electron:

$$K_{max} = h\nu - W_0$$

Wave-Particle duality

- Experiments by Davisson-Germer (1923) and Thompson showed electrons can be diffracted like wave.

- de Broglie hypothesis:

Matter also possesses wave like behaviour. The associated wavelength for a matter with momentum p is given by:

$$\lambda = \frac{h}{p}$$