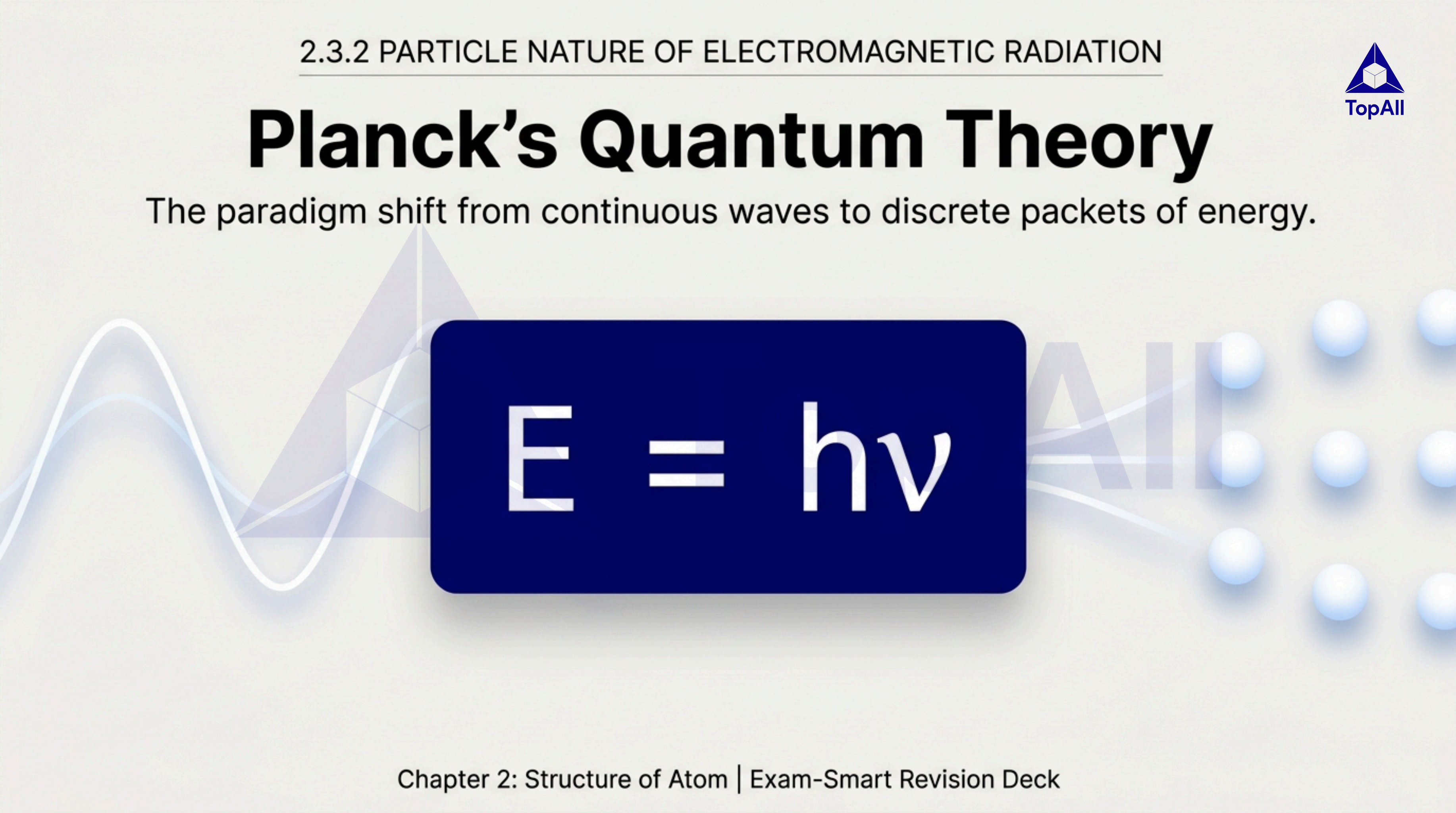


Planck's Quantum Theory

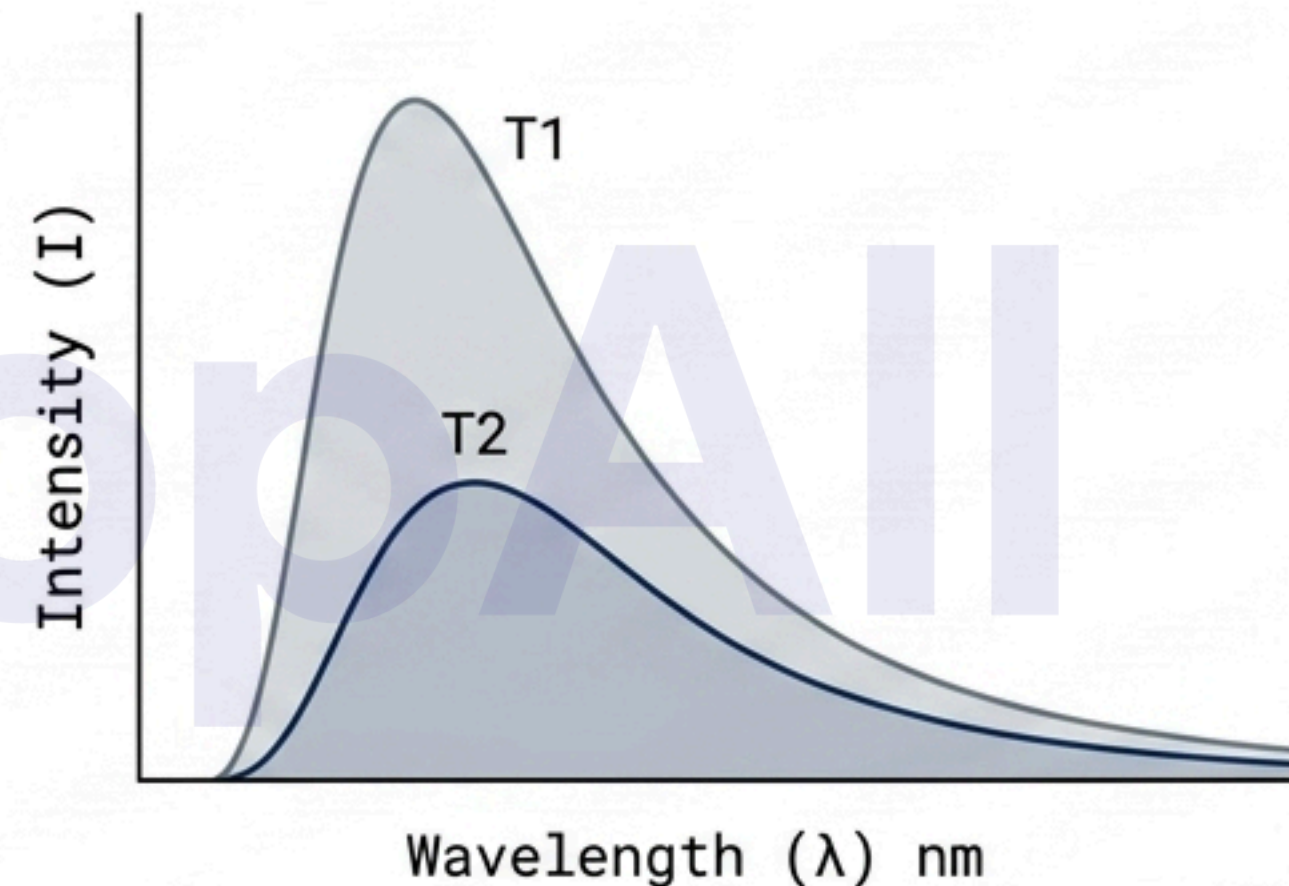
The paradigm shift from continuous waves to discrete packets of energy.


$$E = h\nu$$

The Black Body Enigma

What is a Black Body?

- An ideal body that perfectly emits and absorbs radiations of all frequencies.
- When heated, it emits thermal radiation. As temperature increases, the dominant wavelength of the emitted light becomes shorter (shifting from red to blue).



Experimental data showing intensity peaks at a specific wavelength, then drops sharply.

The Limits of the Wave Theory

Continuous Energy

19th-century electromagnetic theory predicted that energy is emitted continuously.

Result: It predicted that radiation intensity should keep increasing infinitely as wavelength gets shorter—a mathematical impossibility known as the Ultraviolet Catastrophe.



The Observation

Actual experiments proved the classical prediction false. Intensity does not go to infinity at short wavelengths.

Result: A sharp peak is reached, and then intensity rapidly declines.



Classical physics could not explain the nature of emission of radiation from black bodies. A radical new assumption was required.



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$$E=mc^2$$



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THE BREAKTHROUGH (1900)

Energy in Discrete Chunks

Atoms and molecules can emit or absorb energy only in discrete quantities, not in a continuous manner.

The Oscillator

Absorption and emission arise from oscillators (atoms) in the wall of the black body.

The Quantum

Planck gave the name quantum to the smallest possible quantity of energy that can be emitted or absorbed in the form of electromagnetic radiation.



Energy is not a smooth stream; it is a stream of individual, indivisible packets.

The Energy of a Quantum

Energy of a quantum of radiation (measured in Joules, J)

(J)

$$E = h\nu$$

Planck's constant, a universal fixed value

$$6.626 \times 10^{-34} \text{ J s}$$

Frequency of the radiation (measured in Hertz, Hz or s^{-1})

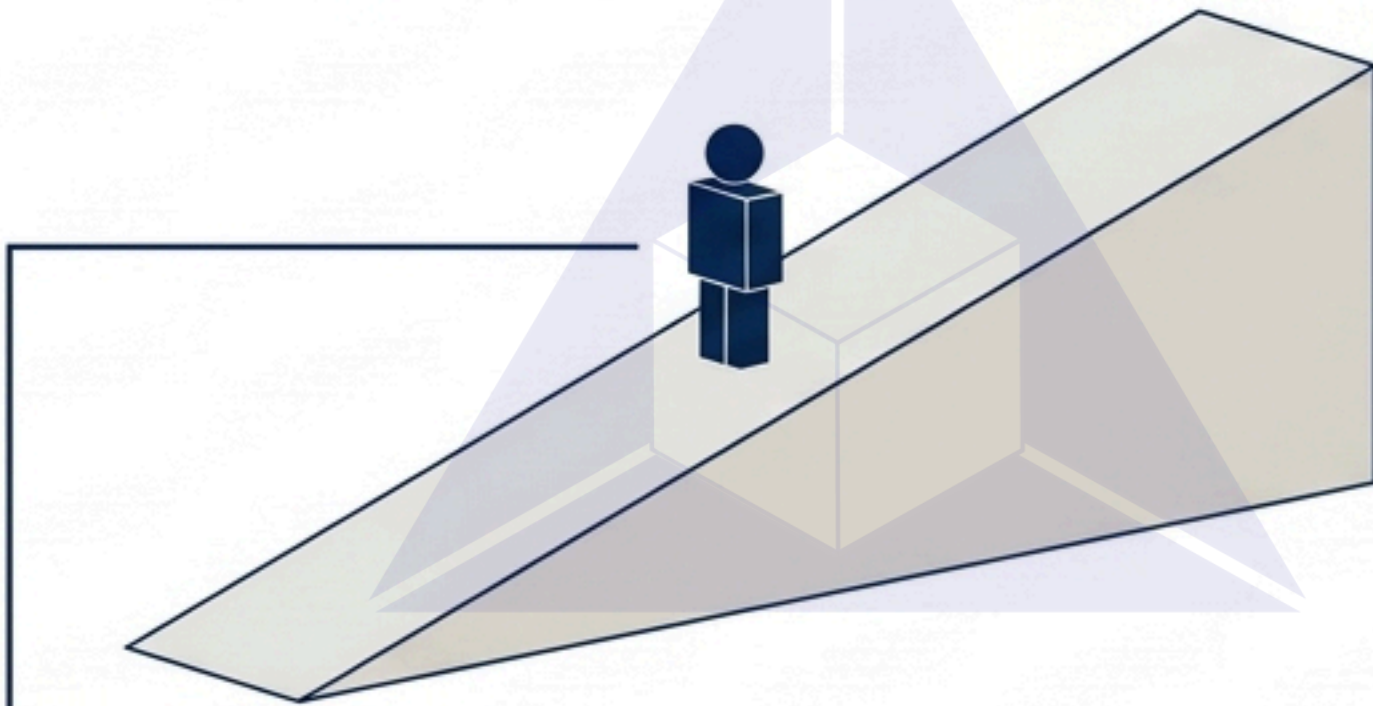
(Hz or s^{-1})

Insight Panel

The energy (E) of a quantum of radiation is strictly proportional to its frequency (ν).
High frequency = High energy per packet.

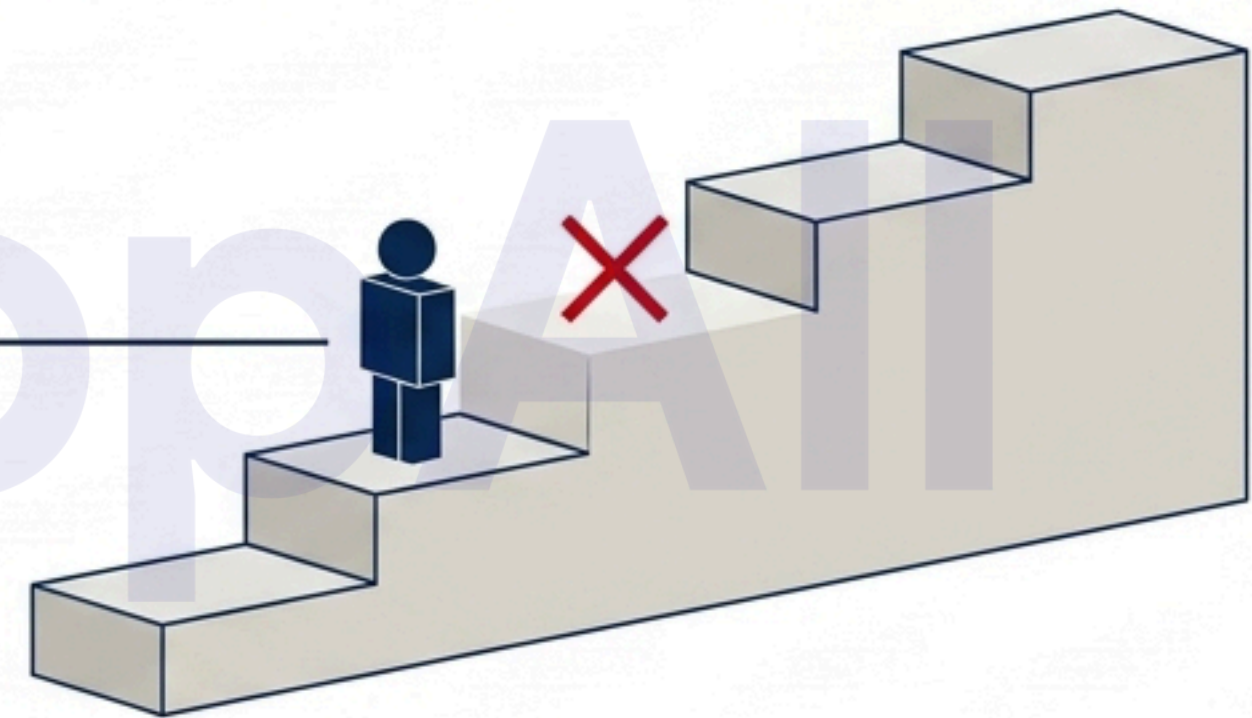
The Staircase vs. The Ramp

The Continuous Ramp



Continuous: Energy can take any value, just like a person can stand at any exact microscopic point on a smooth ramp.

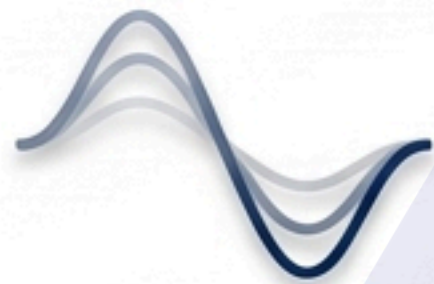
The Quantised Staircase



Quantised: Energy can only take specific, discrete values.

A person can stand on any step, but it is physically impossible to stand suspended in the empty space between two steps.

The Particle Nature of Light



The Failure

Classical continuous wave theory failed to explain Black Body Radiation and the sharp drop-off of light intensity at short wavelengths.



The Quantum

Max Planck solved this by proposing energy is quantized—emitted or absorbed only in distinct, indivisible chunks called quanta.



The Equation

$E = h\nu$ dictates that a quantum's energy is directly proportional to its frequency, anchored by the universal Planck's constant ($6.626 \times 10^{-34} \text{ J s}$).

Light energy is not a continuous wave, but a shower of discrete packets. This assumption successfully laid the foundation for modern quantum mechanics and Einstein's explanation of the photoelectric effect.



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