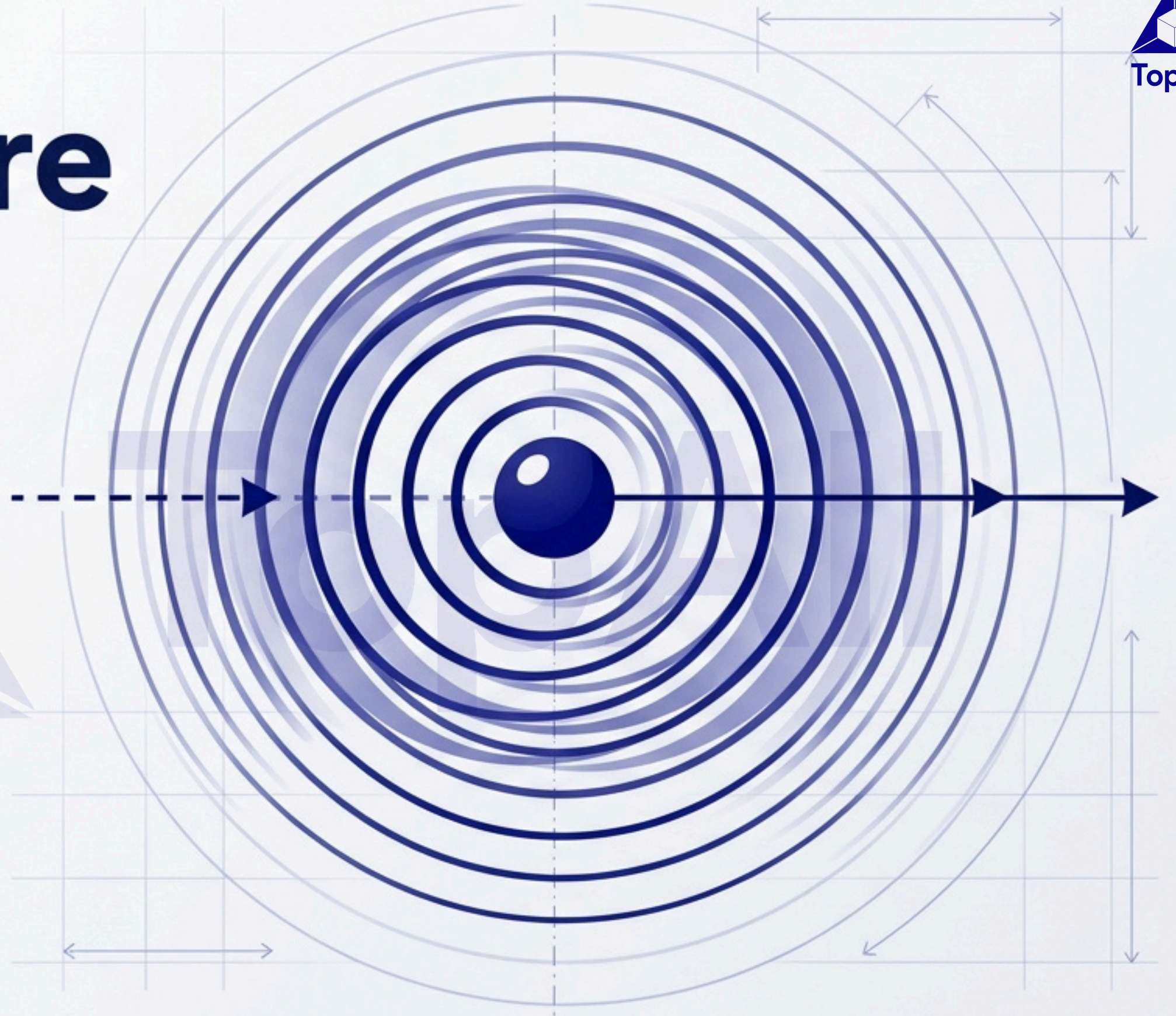


Wave Nature of Matter

de Broglie's revolutionary idea



The Symmetry Question

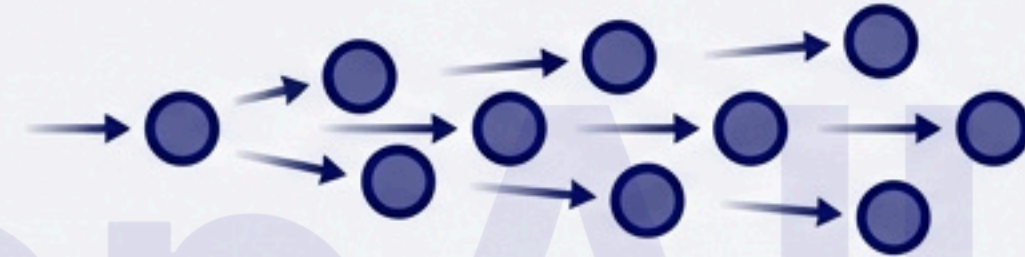
Nature loves symmetry. The two basic physical entities—matter and energy—must have symmetrical character.

Light / Radiation

Wave Nature



Particle Nature



Matter

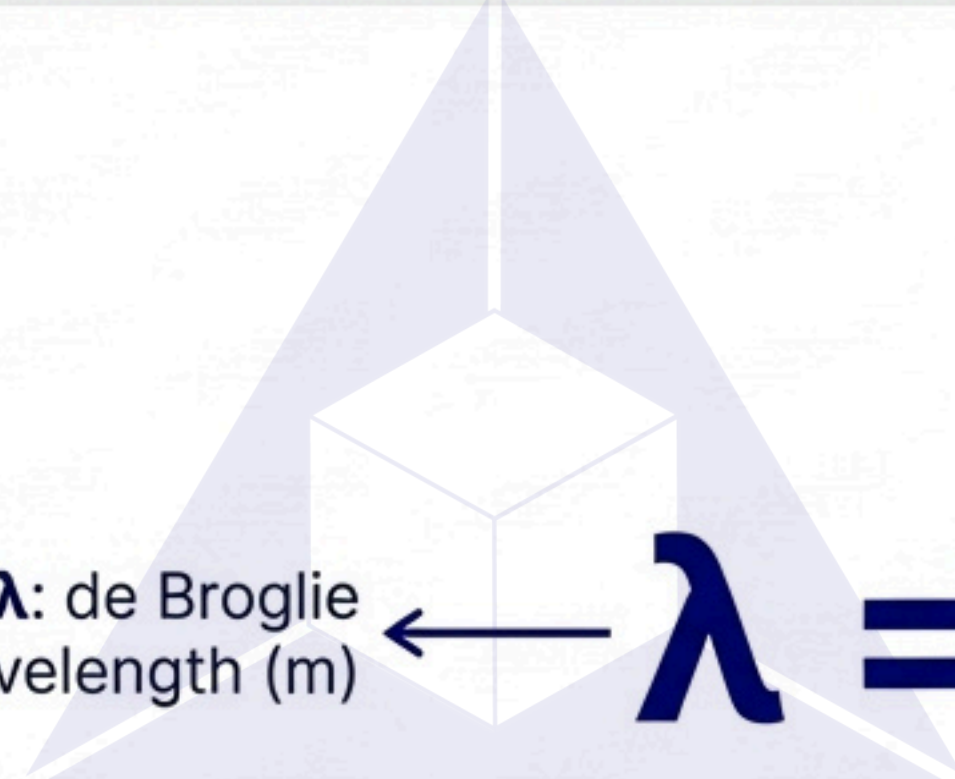
Particle Nature



Can matter also have a wave nature?

The de Broglie Hypothesis

In 1924, Louis Victor de Broglie proposed that moving particles of matter display wave-like properties under suitable conditions.



λ : de Broglie Wavelength (m)

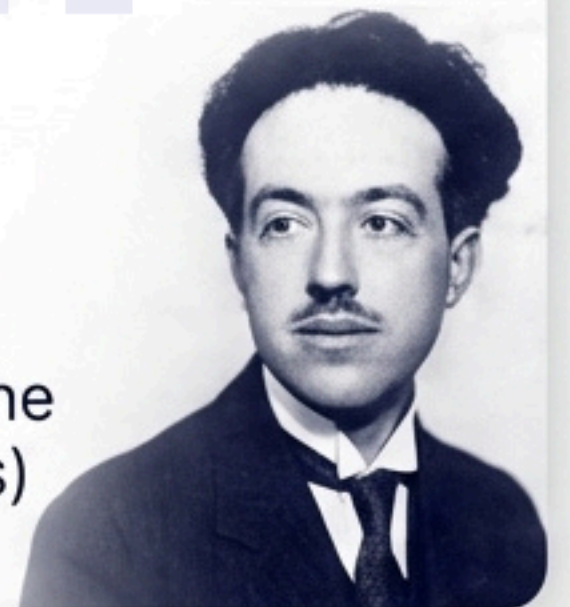
$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

h : Planck's constant
(6.63×10^{-34} J s)

p : Momentum
(kg m/s)

m : Mass of the particle (kg)

v : Velocity of the particle (m/s)





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$$E=mc^2$$



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Key Highlights

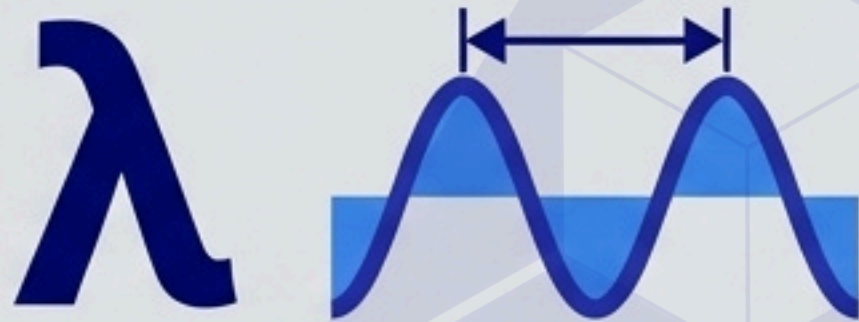
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Bridging Two Worlds

The dual aspect of matter is inherent in a single equation.

Wave Lexicon



Represents the spatial extent and continuous nature of a wave.



The Universal Translator.

Particle Lexicon



Represents the localized, tangible attributes of a moving mass.

Consistency with the Photon

Does the de Broglie relation work for light? Yes. The matter-wave equation perfectly yields the known wavelength of a photon.

Step 1: Energy & Momentum of a Photon

$$p = \frac{h\nu}{c}$$

From Einstein's quantum theory of light.

Step 2: Universal Wave Relationship

$$\frac{c}{\nu} = \lambda$$

Speed of light divided by frequency equals wavelength.

Step 3: Substitution

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

Rearranging the terms perfectly derives the de Broglie relation for a photon.

Why We Don't See Matter Waves Daily

Because macroscopic objects have massive momentum, their de Broglie wavelength is too infinitesimally small to measure.

Macroscopic



Mass = 0.12 kg

Speed = 20 m/s

Calculation:

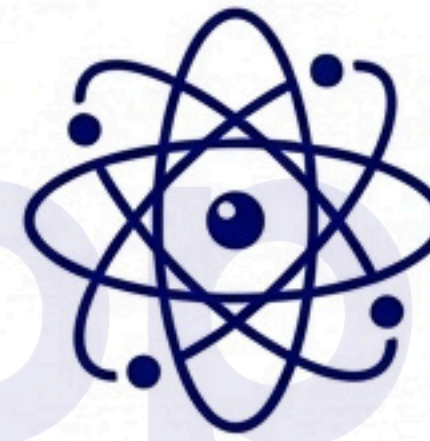
$p = 2.40 \text{ kg m/s}$

Result: $\lambda = 2.76 \times 10^{-34} \text{ m}$

Beyond any measurement

VS

Microscopic



Mass = $9.11 \times 10^{-31} \text{ kg}$

Speed = $5.4 \times 10^6 \text{ m/s}$

Calculation:

$p = 4.92 \times 10^{-24} \text{ kg m/s}$

Result: $\lambda = 0.135 \text{ nm}$

Comparable to X-rays

10^{-34} m Macroscopic Wavelength (Too Small)

p^+ Size of a Proton



Chapter Synthesis: The Quantum Blueprint



Whether a particle or wave description is best suited depends entirely on the nature of the experiment.

01

Universal Property

Every moving particle of matter has an associated de Broglie wavelength ($\lambda = h/p$).

02

The Scale Limit

Matter wave effects are only measurable and physically significant for microscopic, sub-atomic particles (like electrons) due to their tiny mass.

03

Perfect Duality

The universe is fundamentally dual. Both radiation and matter exhibit symmetrical particle-wave characteristics.



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