Matter Waves

De Broglie: the dual (wave-particle) behavior of radiation applies to matter (symmetry of nature)

• A photon (zero rest mass particle) has a light wave associated with it that governs its motion
• A particle with non-zero rest mass has an associated matter wave that governs its motion.
Matter Waves

De Broglie: the total energy of an entity $E$ (momentum $p$) is related to the frequency $\nu$ (wavelength $\lambda$) of the wave associated with its motion:

\[ E = h\nu, \quad p = h/\lambda \]

predicts the de Broglie wavelength $\lambda$ of a matter wave associated with the motion of a particle with momentum $p$.

\[ h \approx 6.6 \times 10^{-34} \text{ J} \cdot \text{s} \]

\[ J = \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} \]

Thompson (1927) – diffraction of electron beams passing through thin films and independently confirmed the de Broglie relation.
Question:

What’s the de Broglie’s wavelength $\lambda$ (in meters) defined as $\lambda = h/p$ of a baseball of 1kg moving at a speed of 10m/s? 

a) Calculate it or b) use an online calculator.

Hint for a) : This is a non-relativistic case: $v << c \Rightarrow p = mv$

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The wave nature of light/matter propagation is not revealed by experiments when the important dimensions of the apparatus used are very large compared to the wavelength of light/matter.
Non-zero mass particles
e.g. electrons, protons

\[
m_0 \neq 0
\]

\[
E^2 - p^2 c^2 = \left( m_0 c^2 \right)^2
\]

\[
\nu \lambda = v_p \neq c
\]
Phase velocity

**Particle**

\[
m_0 \neq 0
\]

\[
E = h \nu
\]

\[
p = h/\lambda
\]

**Associated wave**

De Broglie