

The Quantum Universe II: Wave-Particle Duality

(HON210/Pruett)

"I think I can safely say that nobody understands quantum mechanics." **Richard Feynman** (QU, p. 1)
"God does not play dice." **Albert Einstein** *"Albert, stop telling God what to do."* **Niels Bohr**
"Recent decades have taught us that physics is a magic window. It shows us the illusion that lies behind reality--and the reality that lies behind illusion." **John Wheeler** (BSS, p. 31)

I. The Peculiar Nature of Light

- a) In special relativity—Light, the messenger between frames of reference
- b) In general relativity—particles whose paths defines geodesics in space-time
- c) In quantum mechanics—both wave and particle!

II. Light Behaving Like a Wave (QU, pp. 6-12)

- a) A double-slit experiment with "bullets"
- b) A double-slit experiment with water waves
- c) Young's double-slit experiment with light (1801) (IBHT, p. 76)

III. Light Behaving Like a Particle

- a) The photo-electric effect (Einstein, 1905, Nobel Prize 1921)
- b) The Compton effect (1923) (ERQ, lecture 12)

IV. Light--Both Wave and Particle!

Bohr's Complementarity: *"Light is a wave and light is a particle. Which it is depends on the experiment. But you can't catch it in the act of simultaneously being both."* (ERQ, lecture 12)

V. The Dual Nature of Matter

- a) The matter waves of Louis de Broglie (1924, Nobel Prize 1929) $\lambda = h/p$ (QU, p. 27)
- b) Bohr's model of the atom (1913) (QU, pp. 46-52)
- c) The energy of photons (Einstein, 1905, Nobel Prize 1921) $E = hf$
- d) The spectral lines of an element (QU, pp. 41-48)

VI. Philosophical Implications—A Great Debate

"... When a quantum particle is being measured (observed), it acts like a particle. When the quantum particle is not being measured, it acts like a wave." (BSS, p. 271) Therefore,

Matter manifests only a tendency to exist until it is observed?!?

References: (QU) *The Quantum Universe*, Tony Hey and Patrick Walters, Cambridge, 1987.
(TS) *The Sciences: An Integrated Approach (Prelim. Ed.)*, J. Trefil and R. M. Hazen.
(ERQ) *Einstein's Relativity and the Quantum Revolution* (video lectures) by R. Wolfson
(BSS) *Bridging Science and Spirit*, Norman Friedman, Living Lake Books, 1994.
(IBHT) *The Illustrated A Brief History of Time*, Stephen Hawking, Bantam, 1996.