QUANTUM PHYSICS (or "Quantum Mechanics")

That other great revolution of 20th century physics

Chapters 12 & 13

Meaning of "quantum" and "quantized" ?

Applicability of Quantum Physics: the entire realm of the atomic (incl. molecules) and subatomic world – that's *a lot*, given that all ordinary matter consists of atoms!

→ In many ways a *radical* break with core Newtonian concepts!

→ Our most accurate & comprehensive description of the world
→ Unusual in many ways, ultimate impact far beyond S.R.
→ Tremendous philosophical impact (discussions to this day)
→ Randomness/chance built into nature at the microscopic level
→ Particles & waves can't be separated from their surroundings w/o fundamentally altering their character – "measurement impacts the system being measured"

Quantum physics is the foundation for much of modern technology, provides the framework for understanding light and matter from the subatomic to macroscopic domains, and makes possible the most precise measurements ever made.

The basic principles of quantum physics are not necessarily that complicated, but they lead to astonishing outcomes.

Richard Feynman once said, "*I think I can safely say that nobody understands quantum mechanics.*" Well, that's no reason not to try!

There certainly are "spooky" phenomena like quantum entanglement, incomprehensible from the standpoint of classical physics. However, thoroughly tested by experiment & put to applications…..

Quantum physics combines a spectacular record of discovery and predictive success, with foundational perplexities so severe that even Albert Einstein came to believe that it was wrong. This is what makes it such an exciting area of science!

The book uses a somewhat different/original approach to intro quantum physics, based on concept of a **quantized field:**

Field (continuous, spread-out physical entity containing E) that, for reasons we don't fully understand, can only assume certain specific values of E (and other quantities), and no values in between!

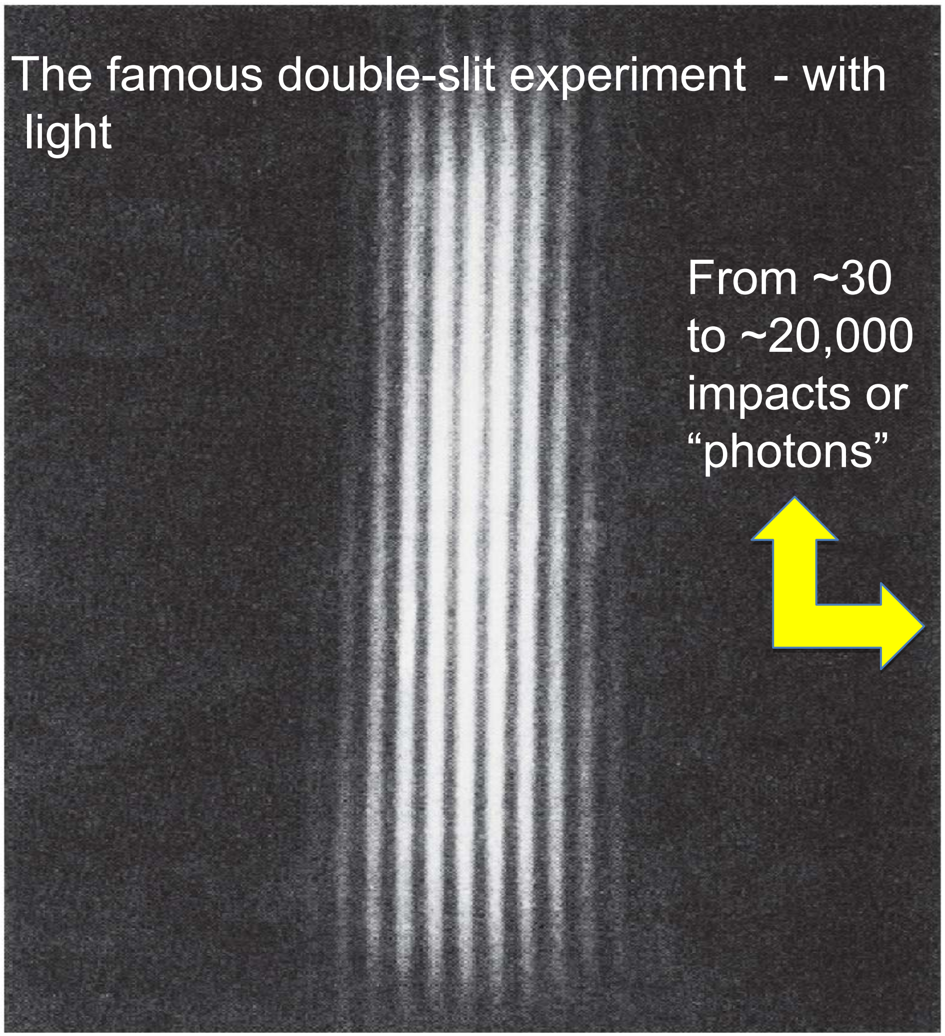
Various consequences to be studied….

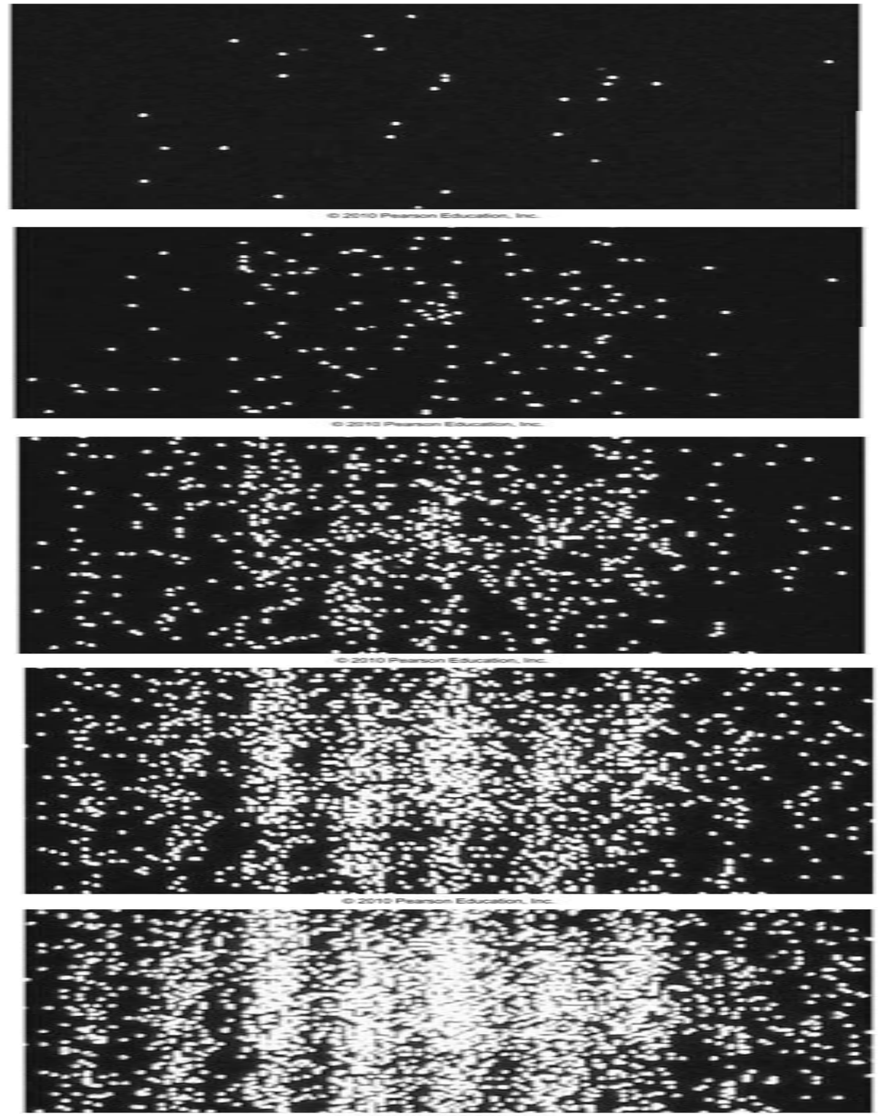
→Quantized field concept applies both to radiation & to matter.

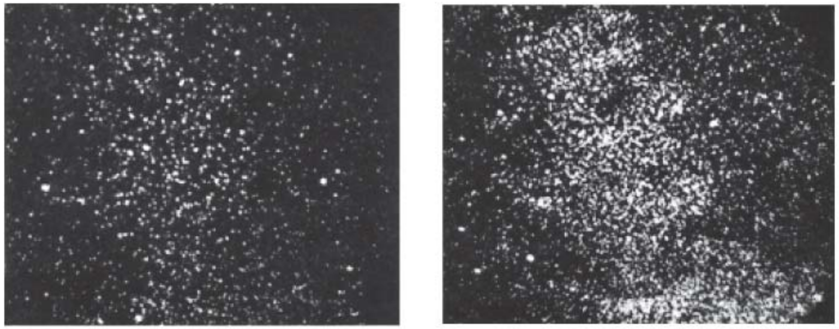
→*All* "*particles*" – photons, electrons, protons, atoms, etc. – are "field quanta", increments of field energy that interact as tiny bundles of energy & momentum.

Planck’s bold hypothesis (1900): light (e&m radiation in general) is quantized according to $E = hf$ - the “photon” hypothesis!

(Important: Planck’s constant h is **tiny**: 6.6×10^{-34} Joule-seconds)

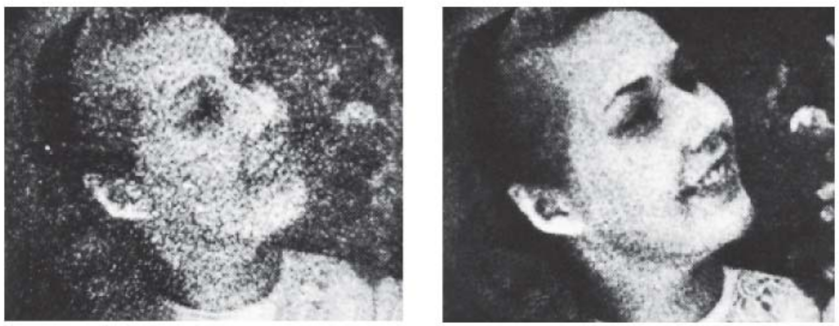






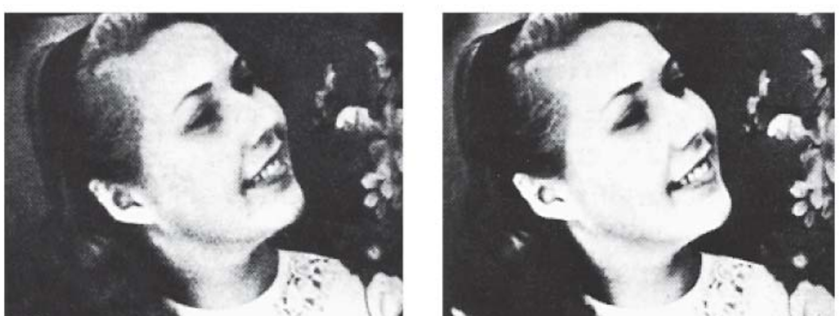
(a) (b)

# of impacts (photons!) increases from



(c) (d)

about 3 × 10^3 to about 3 × 10^7.



(e) (f)

At _low_ intensity we need & see the _quantum picture_: individual photons (“quantized chunks of energy and momentum”) build up the picture.

More photons means what, classically speaking?

Intensity or brightness.

http://www.youtube.com/watch?v=MbLzh1Y9POQ

C.E. 5, 7, 9 – 12 Remember: $E_{photon} = hf$ (Planck)

Quiz # 92: Which has higher energy, a photon of infrared (IR) light or a photon of ultraviolet (UV) light?

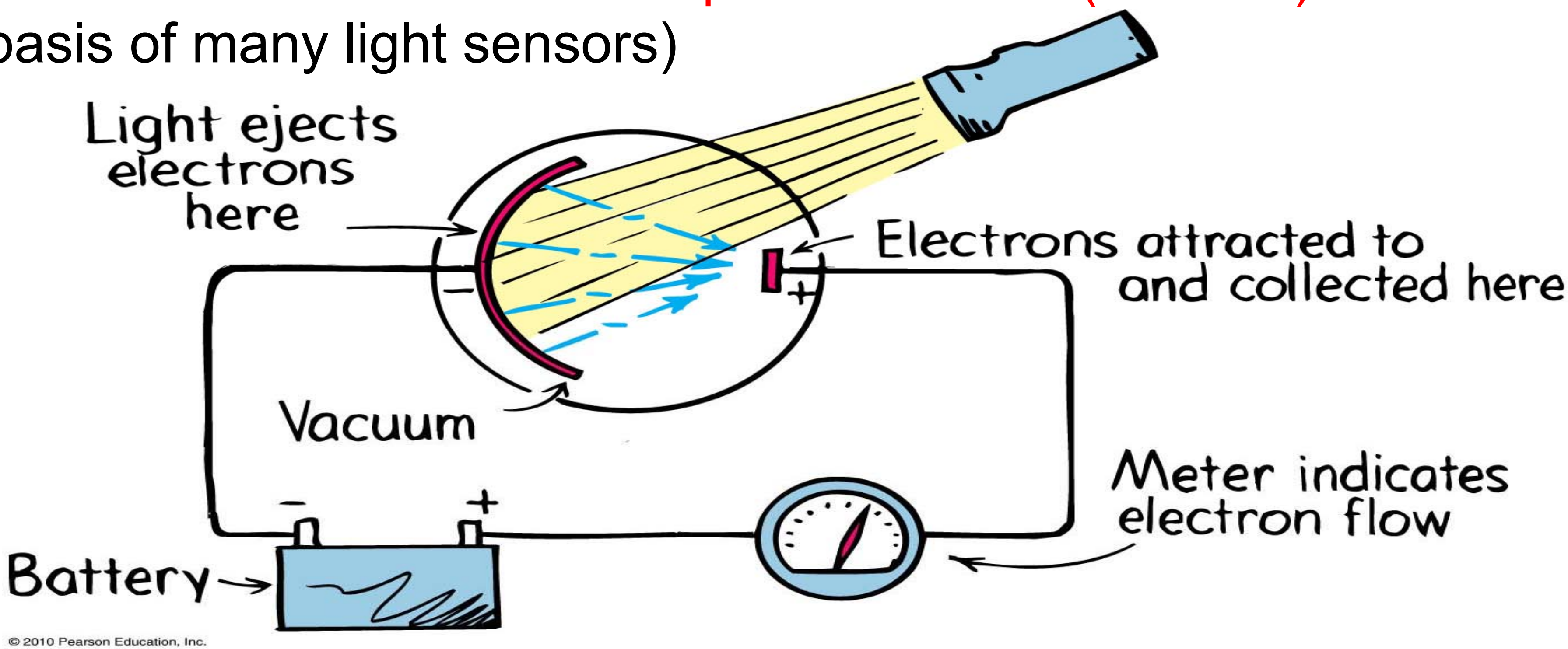
(a) IR (b) UV (c) same energy (d) depends on other things

Quiz # 93: Which of the two photons above is faster (in vacuum)?

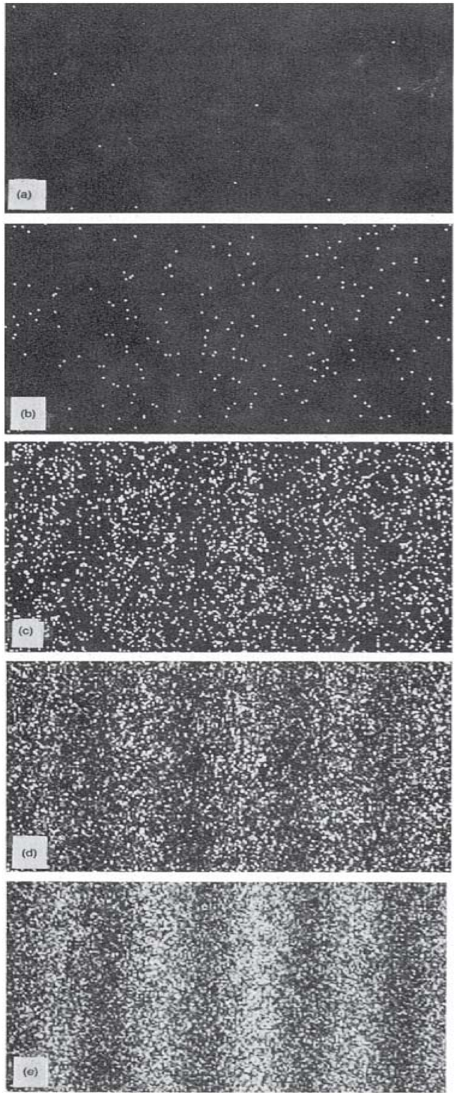
(a) IR (b) UV (c) same speed (d) depends on wavelength

Famous direct evidence for photons: Photo(-electric) effect

(basis of many light sensors)



Remarkable: electrons (or other particles for that matter!) also show a double-slit interference pattern, thereby verifying de Broglie's hypothesis of the (possible) wave nature of classical particles!



From ~10 e^- to ~70,000 per exposure.

→What *waves* here ?
A: a "probability (amplitude)" of finding the particle at the screen. Often referred to in quantum texts as the "wavefunction" (Ψ).

→Sometimes (historically) called "*wave-particle duality*"

de Broglie's relation:

$\lambda = h/p = h/mv$

(wavelength of matter waves = h/momentum)

Quiz # 94: Which has the smaller de Broglie λ, an electron or a proton?

(a) They have the same λ.

(b) electron

(c) proton

(d) Not enough info given.