Modern Physics PHYS 351 — "Summery of corpuscular nature of light "

July 29, 2017

Salwa Alsaleh, PhD
King Saud University

The work of Maxwell and Hertz in the late 1800s conclusively showed that light, heat radiation, and radio waves were all electromagnetic waves differing only in frequency and wavelength. Thus it astonished scientists to find that the spectral distribution of radiation from a heated cavity could not be explained in terms of classical wave theory. Planck was forced to introduce the concept of the quantum of energy in order to derive the correct blackbody formula. According to Planck, the atomic oscillators responsible for blackbody radiation can have only discrete, or quantized, energies given by

$$E = nh\nu \tag{1}$$

where n is an integer, h is PlanckâĂŹs constant, and ν is the oscillatorâĂŹs natural frequency. The black body spectrum is given by the graph in figure Planck quantized the energy of atomic oscillators, but Einstein extended

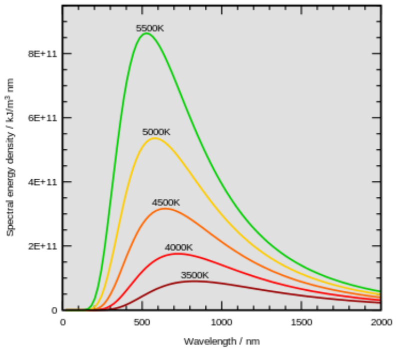

Figure 1: The blackbody spectrum for different temperatures

the concept of quantization to light itself. In EinsteinâĂŹs view, light of frequency ν consists of a stream of particles, called photons, each with energy $E = h\nu$. The photoelectric effect, a process in which electrons are ejected from a metallic surface when light of sufficiently high frequency is incident on the surface, can be simply explained with the photon theory. According to this theory, the maximum kinetic energy of the ejected photoelectron, T_{max}, is given by

$$T_{max} = h\nu - \phi, \tag{2}$$

where ϕ is the work function of the metal.

Although the idea that light consists of a stream of photons with energy

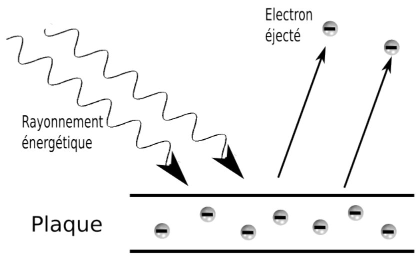

Figure 2: The photoelectric effect

$h\nu$ was put forward in 1905, the idea that these photons also carry momentum was not experimentally confirmed until 1923. In that year it was found that x-rays scattered from free electrons suffer a simple shift in wavelength with scattering angle, known as the Compton shift.When an x-ray of frequency ν is viewed as a particle with energy hf and momentum $h\nu/c$, x-rayâĂŞelectron scattering can be simply analysed to yield the Compton shift formula:

$$\Delta\lambda = \frac{h}{m_e c}\left(1 - \cos\theta\right) \tag{3}$$

Here, m_e is the mass of the electron and θ is the x-ray scattering angle. The striking success of the photon theory in explaining interactions between light and electrons contrasts sharply with the success of classical wave theory in explaining the polarization, reflection, and interference of light. This leaves us with the dilemma of whether light is a wave or a particle The currently accepted view suggests that light has both wave and particle characteristics and that these characteristics together constitute a

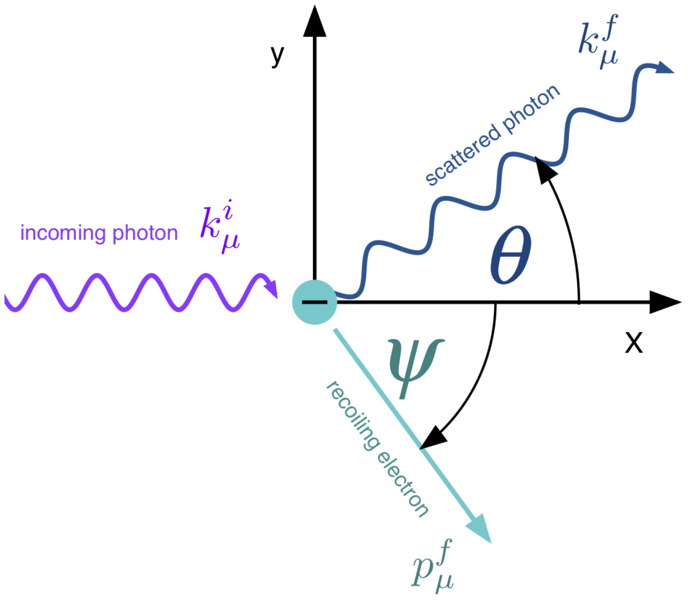

Figure 3: Compton diffusion

complementary view of light.

> *In quantum physics, the distinction between a wave and a particle is not present.*

Reference

Al Saleh, S. (2016a). Calculation of the covariant matrix elements, and cross-sections of compton diffusion on a bound electron. *The European physical journal plus*, 131(10):364.

Al Saleh, S. (2016b). Relativistic dynamics of the compton diffusion on a bound electron. *The European Physical Journal Plus*, 131(5):146.

Bowler, M. G. (2012). *Lectures on statistical mechanics*. Newnes.

Eisberg, R. M., Resnick, R., Lea, S. M., and Burke, J. R. (1961). *Modern Physics*. New York: John Wiley and Sons.

Heisenberg, W. (1958). Physics and philosophy: The revolution in modern science.

Jauch, J. M. and Morrow, R. A. (1968). Foundations of quantum mechanics. *American Journal of Physics*, 36(8):771–771.

Mandl, F. (1971). *Statistical Physics*. Wiiley.