2.6: Quantum Theory of Light

According to Einstein's quantum theory of light, a monochromatic light-wave of angular frequency ω, propagating through a vacuum, can be thought of as a stream of particles, called *photons*, of energy

$$E = \hbar\,\omega, \tag{2.6.1}$$

where $\hbar = h/2\pi = 1.0546\times10^{-34}\,\mathrm{J\,s}$. Because classical light-waves propagate at the fixed velocity c, it stands to reason that photons must also move at this velocity. According to Einstein's special theory of relativity, only massless particles can move at the speed of light in vacuum . Hence, photons must be massless. Special relativity also gives the following relationship between the energy E and the momentum p of a massless particle ,

$$p = \frac{E}{c}. \tag{2.6.2}$$

Note that the previous relation is consistent with Equation (2.4.12), because if light is made up of a stream of photons, for which $E/p = c$, then the momentum density of light must be the energy density divided by c. It follows, from the previous two equations, that photons carry momentum

$$p = \hbar\,k \tag{2.6.3}$$

along their direction of motion, because $\omega/c = k$ for a light-wave. [See Equation (2.4.5).]

Contributors and Attributions

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