Observations INCONSISTENT with laws of classical physics (~1900)

Experiment	'Classical expectation'	Observation	Implication and resolution	Formulas
Ultraviolet Catastrophe	A heated 'black body' would emit an 'infinite' intensity of radiation as λ got smaller (ν larger) i.e. 'approaching the UV region'	The observed I (intensity) vs λ was well behaved, peaking at smaller λ for higher temperatures, but NOT catastrophically blowing-up as $\lambda \to 0$	Electromagnetic radiation was composed of small packets of energy called photons.	Planck $E_{photon} = h\nu_{photon}$
Photoelectric Effect	Electromagnetic radiation of high enough intensity, any ν, would cause electron emission (photoelectrons)	a. No emission of electrons if $\nu < \nu_0$, irrespective of intensity b. For $\nu > \nu_0$ KE of photoelectrons increases as ν increases c. For $\nu > \nu_0$ higher intensity light gave MORE photoelectrons, but same KE per electron	a. Photoelectrons ejected only when an individual photon of the EM radiation has sufficient energy to overcome attraction of metal nuclei (this energy is the 'work function' Φ_{metal} of the metal). b. If the photon has energy greater than Φ, the excess energy goes into KE of electron	Einstein-Planck $\Phi = h\nu_0$ (the value of Φ_{metal} depends on the metal) for $\nu > \nu_0$ $h\nu = \Phi + KE$ $h\nu = h\nu_0 + KE$ $KE = h\nu - h\nu_0$

Observations INCONSISTENT with laws of classical physics (~1900) *continued*

Experiment	'Classical expectation'	Observation	Implication and resolution	Formulas
Davisson-Germer	X-rays exhibit wave interference when travelling through 'slits' (between atoms of metal foil) BUT electrons are PARTICLES and should not. For an EM wave, the square of the amplitude, A^2, at a given location is the intensity (brightness) of the wave at that location.	Electrons show wave interference when shot through metal foil and the interference pattern depends on velocity of electrons (and spacing of atoms in metal foil)	Electrons (PARTICLES) have WAVE-LIKE properties. For a particle wave, the square of the amplitude, A^2, at a given location gives the PROBABILITY that the particle will be measured to be at that location !!!	De Broglie $p\lambda = h$ $m\mathrm{v}\lambda_{particle} = h$ $\lambda_{particle} = \frac{h}{m\mathrm{v}}$
Compton	Light (EM radiation) is massless and has no momentum when striking a particle	When light is scattered from electrons, the process of scattering (angles and energies) can be predicted using conservation of MOMENTUM of particle and radiation.	Light (EM radiation) has the PARTICLE-LIKE properly of momentum	De Broglie p is momentum $p\lambda = h$ $p_{photon} = \frac{h}{\lambda}$
Exact measurements of position and velocity of a given particle are incompatible	Particles can have a precisely know position and velocity	Attempting to precisely measure the position of a particle introduces uncertainty into the value of its momentum (velocity)	The wave-like nature of particles precludes the simultaneous specification of position and momentum (velocity)	Heisenberg Δ's are UNCERTAINTIES in measurements of x and v $(\Delta x)(\Delta p_x) \geq \frac{h}{4\pi}$ $m(\Delta x)(\Delta \mathrm{v}_x) \geq \frac{h}{4\pi}$