= Photon =

A photon is an elementary particle , the quantum of all forms of electromagnetic radiation including light . It is the force carrier for electromagnetic force , even when static via virtual photons . The photon has zero rest mass and as a result , the interactions of this force with matter at long distance are observable at the microscopic and macroscopic levels . Like all elementary particles , photons are currently best explained by quantum mechanics but exhibit wave ? particle duality , exhibiting properties of both waves and particles . For example , a single photon may be refracted by a lens and exhibit wave interference with itself , and it can behave as a particle with definite and finite measurable position and momentum . The photon 's wave and quanta qualities are two observable aspects of a single phenomenon , and cannot be described by any mechanical model ; a representation of this dual property of light , which assumes certain points on the wavefront to be the seat of the energy , is not possible . The quanta in a light wave cannot be spatially localized . Some defined physical parameters of a photon are listed .

The modern concept of the photon was developed gradually by Albert Einstein in the early 20th century to explain experimental observations that did not fit the classical wave model of light . The benefit of the photon model was that it accounted for the frequency dependence of light 's energy , and explained the ability of matter and electromagnetic radiation to be in thermal equilibrium . The photon model accounted for anomalous observations , including the properties of black @-@ body radiation , that others (notably Max Planck) had tried to explain using semiclassical models . In that model , light was described by Maxwell 's equations , but material objects emitted and absorbed light in quantized amounts (i.e. , they change energy only by certain particular discrete amounts) . Although these semiclassical models contributed to the development of quantum mechanics , many further experiments beginning with the phenomenon of Compton scattering of single photons by electrons , validated Einstein 's hypothesis that light itself is quantized . In 1926 the optical physicist Frithiof Wolfers and the chemist Gilbert N. Lewis coined the name photon for these particles . After Arthur H. Compton won the Nobel Prize in 1927 for his scattering studies , most scientists accepted that light quanta have an independent existence , and the term photon was accepted .

In the Standard Model of particle physics , photons and other elementary particles are described as a necessary consequence of physical laws having a certain symmetry at every point in spacetime . The intrinsic properties of particles , such as charge , mass and spin , are determined by this gauge symmetry . The photon concept has led to momentous advances in experimental and theoretical physics , including as lasers , Bose ? Einstein condensation , quantum field theory , and the probabilistic interpretation of quantum mechanics . It has been applied to photochemistry , high @-@ resolution microscopy , and measurements of molecular distances . Recently , photons have been studied as elements of quantum computers , and for applications in optical imaging and optical communication such as quantum cryptography .

= = Nomenclature = =

In 1900 , the German physicist Max Planck was studying black @-@ body radiation and suggested that the energy carried by electromagnetic waves could only be released in " packets " of energy . In his 1901 article in Annalen der Physik he called these packets " energy elements " . The word quanta (singular quantum , Latin for how much) was used before 1900 to mean particles or amounts of different quantities , including electricity . In 1905 , Albert Einstein suggested that electromagnetic waves could only exist as discrete wave @-@ packets . He called such a wave @-@ packet the light quantum (German : das Lichtquant) . The name photon derives from the Greek word for light , ??? (transliterated phôs) . Arthur Compton used photon in 1928 , referring to Gilbert N. Lewis . The same name was used earlier , by the American physicist and psychologist Leonard T. Troland , who coined the word in 1916 , in 1921 by the Irish physicist John Joly , in 1924 by the French physiologist René Wurmser (1890 @-@ 1993) and in 1926 by the French physicist Frithiof Wolfers (1891 @-@ 1971) . The name was suggested initially as a unit related to the illumination of the eye and the resulting sensation of light and was used later in a physiological

context . Although Wolfers 's and Lewis 's theories were contradicted by many experiments and never accepted , the new name was adopted very soon by most physicists after Compton used it .

In physics , a photon is usually denoted by the symbol ? (the Greek letter gamma) . This symbol for the photon probably derives from gamma rays , which were discovered in 1900 by Paul Villard , named by Ernest Rutherford in 1903 , and shown to be a form of electromagnetic radiation in 1914 by Rutherford and Edward Andrade . In chemistry and optical engineering , photons are usually symbolized by h? , the energy of a photon , where h is Planck 's constant and the Greek letter ? (nu) is the photon 's frequency . Much less commonly , the photon can be symbolized by hf , where its frequency is denoted by f .

= = Physical properties = =

A photon is massless , has no electric charge , and is a stable particle . A photon has two possible polarization states . In the momentum representation of the photon , which is preferred in quantum field theory , a photon is described by its wave vector , which determines its wavelength ? and its direction of propagation . A photon 's wave vector may not be zero and can be represented either as a spatial 3 @-@ vector or as a (relativistic) four @-@ vector ; in the latter case it belongs to the light cone (pictured) . Different signs of the four @-@ vector denote different circular polarizations , but in the 3 @-@ vector representation one should account for the polarization state separately ; it actually is a spin quantum number . In both cases the space of possible wave vectors is three @-@ dimensional .

The photon is the gauge boson for electromagnetism , and therefore all other quantum numbers of the photon (such as lepton number , baryon number , and flavour quantum numbers) are zero . Also , the photon does not obey the Pauli exclusion principle .

Photons are emitted in many natural processes . For example , when a charge is accelerated it emits synchrotron radiation . During a molecular , atomic or nuclear transition to a lower energy level , photons of various energy will be emitted , ranging from radio waves to gamma rays . A photon can also be emitted when a particle and its corresponding antiparticle are annihilated (for example , electron ? positron annihilation) .