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Emergence of Modern Physics

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Abstract

When we are dealing with the subject physics, we deal with nature and natural phenomenon. Physics dealing with all physical quantities before the year 1900 was termed as classical physics. But with the onset of the 20^{th} century, it was found that some of the facts observed couldn't be explained by the theories given in classical mechanics. So the necessity of new theory was inevitable. This theory was given the name – modern physics; which explained all the facts which couldn't be explained by classical mechanics. The difference between the two is that classical physics is based on the concept of determinism and quantum physics is based on probabilistic approach.

Keywords: *Modern Physics, Classical Physics, Blackbody Radiation.*

1. Introduction

Before 1900, the physics was termed as classical physics. Classical physics provides extremely accurate results, when the area of the research is limited to massive objects and the speeds taken into attention do not access the speed of light. Basic concept of classical mechanics is that it often deals actual world objects as point particles, objects which are of tiny size [1, 2]. The movement of this type of particle is identified by different parameters like its position, mass and the force applied to it. In substance the type of object that classical mechanics can characterize have a non-zero size, however objects with non-zero size have more difficult behavior than hypothetical point particle, logic being the additional degree of freedom –for instance a baseball can rotate during its movement. Still, the product obtained for point particle can be used for research of different objects, by considering them as complex objects, made up of a huge number of communicating point particles [3]. The center of mass of such a complex object acts similar to a point particle. Classical mechanics develops sound ideas of how matter and force prevail and communicate with each other [4].

Isaac Newton proposed three laws of motion- the law of inertia, law of acceleration, the law of action and reaction and hence laid the foundation of classical mechanics on the basis of his observations. Newton was also the first to support earliest accurate scientific and mathematical formulation of gravity in Newton's law of universal gravitation. He was the first to formulate the adequate and most appropriate description of classical mechanics by using the laws of motion and gravitation in combo. Specifically, Newton procured a theoretical clarification of Kepler's laws of motion of the planets. Isaac Newton and his contemporaries with the remarkable exception of Huygens (who gave the concept of light as a wave), believed that classical mechanics would be adequate to resolve all phenomenon including light in the pattern of geometric optics. Newton even explained the phenomenon of Newton's rings in terms of his own corpuscular theory of light.

According to classical physics matter and energy are two separate entities. Classical physics has been classified into several different realms particularly mechanics, dynamics, hydrodynamics, statics, optics, thermodynamics (studying energy and heat) and acoustics, in addition to the phenomenon surrounding magnetism and electricity. Classical mechanics is an approach established on certain facts and detailed observations. Generally theories are based on some specific postulates. Classical mechanics is established on two speculations [5, 6].

I. The **state postulate** which defines what constitutes a complete description of the state of a system.

II. The **time evolution postulate** which tells us how to predict the future state of the system, or reconstruct its past, based on the knowledge of its present state.

2. Failure of Classical Physics

(a) Blackbody Radiation

When the object is at a temperature above absolute zero, it emits light at all wavelengths .If the object is perfectly black that means it does not reflect any light, then the light that comes from it is called blackbody radiation. Energy of such a blackbody radiation is not shared evenly by all wavelengths of light. The observed spectrum of such a blackbody radiation shows that some wavelength gets more energy than other. Three spectra are shown (Fig 1), for three different temperatures.

Some experimental facts about blackbody radiation:

1. Spectrum shown by the blackbody depends only on the temperature of the object and not on what it is made of.

2. When the temperature of an object increases, more blackbody energy is emitted at all wavelengths.

3. With the increase of the temperature of an object the peak wavelength of the blackbody spectrum becomes shorter. E.g., blue stars are hotter than red stars.

4. Spectrum of such a blackbody radiation always grows small at the left hand side (the short wavelength, high frequency side).

Explanation in Terms of Classical Physics:

Light is an electromagnetic wave formed by the vibration of electric charges? In case of a hot object, electrons vibrate in random direction and thus produce light. A hotter object has more energetic vibrations and so thus more light is emitted by it, and thus glows brighter.

According to classical physics the electrons in a hot object can resonate with a wide range of frequencies, varying from a very few vibration per seconds to a large number of vibrations. There is no extent to how large the frequency can be. According to classical physics each frequency of vibration should have identical energy. Since there is no restriction for the frequency, so there is no extent to the energy of the vibrating electrons at high frequency as well. According to classical physics we can conclude that there should be no check to the energy of the light obtained by the electrons resonating at high frequency, which is wrong as per the shape of the blackbody spectrum is considered.

(b) Photoelectric effect

In the beginning of 20th century it was observed that when light gleams on the surface of a metallic substance, electrons in the metal consume the energy of the light and can escape from its surface. This phenomenon was named as photoelectric effect.

Explanation in Terms of Classical Physics:

According to classical physicists of that time the explanation for photoelectric effect was that light is a wave with the energy distributed evenly through out the wave. It was expected that when the dim light falls on the metal surface, it will take some time to eject an electron from the metallic surface. This was proven wrong. But from the experimental observation, if light of a certain frequency can eject electron from a metal, it makes no difference how dim light is. No time delay has been observed.

(c) Hydrogen Atom

A small tube of hydrogen gas when heated begins to glow and emit light. Hydrogen consists of a positively charged proton at the center, with a negatively charged electron orbiting around it. There is an electrical attraction between the positive proton and negative electron, which keeps the electron in orbit, just like the gravitational attraction between the sun and the earth holds the earth in orbit.

Explanation of Classical Physics:

According to the prediction of classical physics the electron in a hydrogen atom should constantly emit radiation, lose energy and then curl into the nucleus. But in reality it does not happen. Therefore, the classical mechanics fails to quantitatively explain the properties of even the simplest of atom.

3. Modern Physics

When a particular theory fails to explain certain facts, we need to amend it. On amendment even if it will not be able to explain such facts, we have to opt for some other theory. Due to non availability of reasons for certain facts in classical physics/mechanics, the need of different type of theory was badly needed with the onset of 20th century. Thus, the term modern physics was coined. This term modern physics generally refers to the study of those facts and theories that concerns the ultimate structure and interaction of matter, space and time in particular.

The first major step was taken by Albert Einstein, for a deeper understanding of the nature of space and time measurement, whose special theory of relativity (1950) resolved the inconsistency between mechanics and electromagnetism. The most important result obtained by Einstein was the equivalence of mass and energy, expressed in the famous equation $E=mc^2$.Special theory of relativity is the real essence of modern physics [7]. The intensity distribution of blackbody radiation was explained by Max Planck. According to his supposition the energy of an electromagnetic radiation is quantized in bunches of amount hv, where v is the frequency and h is a constant. All this occurred several years before Einstein published his special theory of relativity in 1905.Einstein (the father of modern physics) also applied the quantum hypothesis to photons in an explanation of the photoelectric effect. Latest hypothesis was found to be unswerving with special theory of relativity. Also to explain hydrogen atom, Bohr gave his assumptions-that the electron's angular momentum in the hydrogen atom is quantized in discrete amounts which enabled him to explain the positions of the spectral lines in hydrogen. But all these quantization rules achieved only inadequate success. In the year 1924, Louis de Broglie proposed, that waves were associated with material particles; with this the practicalities of a correct quantum theory were laid. In 1926 Schrödinger following the de Broglie implication projected a wave equation describing the propagation of these particle-waves, and developed a quantitative explanation of atomic spectral line intensities, which could not be described by classical physics. This theory was the backbone of modern physics.

Pauli's exclusion principle was recognized austerely, which provided the elucidation for the structure of the periodic table of the elements and for many of the details of the chemical properties of the elements. Somerfield furthermore explained the behavior of electrons in a metal on the foundation of quantum theory. Modern physics has gradually progressed toward the study of the microscopic (subatomic) structure of matter, making use of the newly formulated theories of relativity and quantum mechanics. The fundamental understanding of atomic properties was mainly achieved by the method of Schrödinger's equation in 1926. The discovery of the neutron by Chadwick was really a great achievement in the field of physics; and nuclear fission and nuclear fusion being the byproducts of these studies. At present we have over fifty of the so-called elementary particles, which researchers have discovered. Such types of particles are ordinarily formed by collisions between high-energy particles of some other type, usually nuclei or electrons. Most of the elementary particles are unstable and easily decay into some other more stable objects in a very short span of time, these particles and their communication forms an important branch of present-day research in physics, which has really transformed the present age.

Energy is the most concrete and consolidating concept in modern physics. Although, energy is considered to be a conserved quantity according to classical physics, but Einstein showed that energy and momentum are closely related in the relativistic transformation equations and hence conceptualized the equivalence of energy and mass [8]. De Broglie who gave the quantum relations connected the frequency and wavelength of the wave motion associated with particles, with the particle's energy and momentum. Schrödinger's wave equation was also obtained by mathematical operation done on the physical entity i.e. energy, which was earlier considered to be a conserved quantity. The most recent relativistic quantum theory is established on variational principles, which engages the energy of a system expressed in quantum-mechanical form. Perhaps the most important, the stable stationary states of quantum systems are modes of definite energy and another very important thought is that of probability taken according to quantum physics. Newtonian mechanics, which is rigidly deterministic theory; but with the evolution of quantum theory, it became clear that at microscopic level events could not be exactly predicted or controlled. Hence the probabilistic concept was born.

3.1 Explanation for Blackbody Radiation in Terms Of Modern Physics i.e. Quantum Mechanics

Since the classical theory could not describe the blackbody radiation, the new theory came into existence. In about 1901 Max Planck came up with the solution for blackbody radiation. Contrary to the common belief of classical physics that each frequency of vibration should have the same energy Max Planck stood against it. He believed that energy is not shared equally by electrons that vibrate with different frequencies. Planck suggested that energy comes in clumps and is not continuous, and named such clump of energy a quantum. The size of such a clump of energy depends on the frequency of vibration. In brief he offered a profound concept that electromagnetic radiation was obtained in distinct bundles of energy. Planck's rule for a quantum of energy for a vibrating electron is given by:

Energy of a quantum = (a calibration constant) x (frequency of vibration)

$E = h\upsilon$, where h=Planck's constant

Here any electron vibrating with a frequency υ, could only have an energy of $1h\upsilon$, $2h\upsilon$, $3h\upsilon$, $4h\upsilon$, that is,

Energy of vibrating electron = (any integer) x $h\upsilon$

According to Planck electron requires at least one quantum of energy for vibration. If it doesn't have at least energy of $1h\upsilon$, its vibration is unattainable and it can't produce any light. Towards high frequency the load of energy is so large that it is not feasible for high vibrations to begin and this is why the blackbody spectrum grows small at the left hand (high frequency side).

3.2 Explanation for Photoelectric Effect in Terms of Modern Physics i.e. Quantum Mechanics

There was no satisfactory explanation for photoelectric effect for quite a long time. In 1905, it was Einstein who broadened Planck's idea of quantization to electromagnetic wave. According to Einstein light can be assumed to be of frequency υ and can be considered as a stream of quanta, regardless of the source of the radiation. Now these quanta are known as photons of energy E, given by $E=h\upsilon$. A photon of the incident light contributes all its energy $h\upsilon$ to a single electron in the metal. Therefore the assimilation of energy by the electrons is not a continuous intake process as was according to classical wave model for light; rather it is a discontinuous process in which energy is delivered to electrons in discrete packets. Electrons discharged from the metal surface that do not smash with other metal atoms before departing own the maximum kinetic energy K_{max} .As per Einstein's rule the highest kinetic energy for these free electrons is

$$K_{max} = h\upsilon - \varphi$$

Φ = work function of the metal. The work function denotes the minimum energy with which an electron is bound in the metal.

So, $K + \Phi = h\upsilon$

3.3 Explanation for Hydrogen Atom in Terms of Modern Physics i.e. Quantum Mechanics

Classical physics could not describe hydrogen atom, but the concept of quantum mechanics explained it. The spectral frequency of the hydrogen atom was first of all given by Niel's Bohr in the year 1913, by making use of a number of assumptions in terms of the quantization rule. The assumptions made by him were not fully correct but for the hydrogen atom correct results could be obtained. Although the model given by him is considered outmoded and has been completely substituted by a probabilistic quantum mechanical theory which was given by Schrödinger in the year 1926. The solution for the hydrogen atom is analytical giving a simple interpretation for the hydrogen energy levels; According to Schrödinger equation the predicament of the hydrogen atom is to replace the appropriate potential energy function into the Schrödinger's equation.

4. Importance of Modern Physics

4.1 Quantum Mechanical Concepts in Electronics and Electronic Devices

Quantum mechanics which has given the idea of tunneling indicates to the quantum mechanical phenomenon where a molecule tunnels through an obstacle which according to classical mechanics is impractical. Tunneling has significant utilization to present day devices such as the tunnel diode and the scanning tunneling microscope [9]. The impact of tunneling was predicted in the early 20^{th} century and its approval, as a general physical phenomenon, came in mid-century [10].

Nanoelectronic devices which are established on the phenomenon of nanoscience, where structures whose material properties alter on an atomic length scale are taken into consideration. Such type of structures can be developed with an array of experimental ways in a collection of different material systems. Interfaces amid peculiar type of materials can be atomically sudden. These sudden interfaces indeed facilitate device designers to restrict electrons quantum mechanically, which alters the properties of materials extremely thus paying the way for modern device applications.

4.2 Condensed Matter Physics

Investigations in condensed matter physics have resulted in various device applications, as in the area of the semiconductor transistors, and as well as in the laser technology [11]. Currently various condensed matter systems are under investigation with potential utility to quantum computation, in addition to experimental systems like quantum dots, SQUIDs (Superconducting quantum interference devices)[12, 13]. Condensed matter systems offer the environment of coherence and phase-sensitivity that are essential components for quantum information storage. Spintronics, which is stationed on spin and not on the electron transport, is a current area of technology applied for information processing and transmission. Researches conducted worldwide have proven that condensed matter physics has substantial advantage to biophysics, especially in the experimental technique of magnetic resonance imaging, which is broadly used in medical diagnosis for various conditions.

4.3 Medicine and Modern Physics

Whether or not the level of subatomic structures or elementary particles has been achieved is proven by the fact that the study of the human body advances beyond the level of cells, molecules, and atoms. The approach of modern physics has proved that elementary particles can no longer be assumed as corporeal structures, in the sense of the Cartesian res extensa. Heisenberg (Physicist) even attributed these elementary particles as being strictly related to Plato's forms [14]. Modern natural science contradicts the constant support of Cartesian concept of res extensa (extended or corporeal substance) and res cogitans (thinking substance). Medicines must react to the improvement in its natural scientific base but for both entities i.e corporeal substance and thinking substance. The old age rigid partition between mind and body needs to be overthrown and an integrated approach to the patient should be encouraged.

4.4 Modern Particle Physics and Nuclear Physics

The investigation of the elementary constituents of matter and energy, and the communication between them is accepted as particle physics [15]. Particle physicists devise and develop the high energy accelerators, detectors, and computer programs [16, 17, 18]. Many elementary particles are generated during high-energy impact of other particles and so particle physics is also sometimes termed as "high-energy physics" [19].

The interactions of elementary particles and http://en.wikipedia.org/wiki/Field_(physics) fields are analysed in terms of the Standard Model [20]. This model accounts for the twelve known particles of matter e.g quarks and leptons that interact via the strong, weak, and electromagnetic fundamental forces [20]. Dynamics of this model describes in terms of matter particles exchanging gauge bosons (gluons, W and Z bosons, and photons, respectively) [21]. The Standard Model had also predicted a particle "God particle" known as the Higgs boson [20]. CERN, the European laboratory in July 2012, announced the detection of a particle consistent with the Higgs boson [22].

Nuclear Physics investigates the components and interplay of atomic nuclei. Nuclear physics finds its utility mainly for nuclear power generation and nuclear weapons technology, but this field of study has offered application in many fields, like geology, archaeology, nuclear medicine, magnetic resonance imaging, ion implantation in materials engineering, and even radiocarbon dating. Classical physics undoubtedly is the real physics but the present age of science couldn't be perceived without modern physics. It is also true that everything in this world has some pros and cons. It is for the mankind to think whether they want to save the human race or not, especially when we talk about the nuclear armaments.

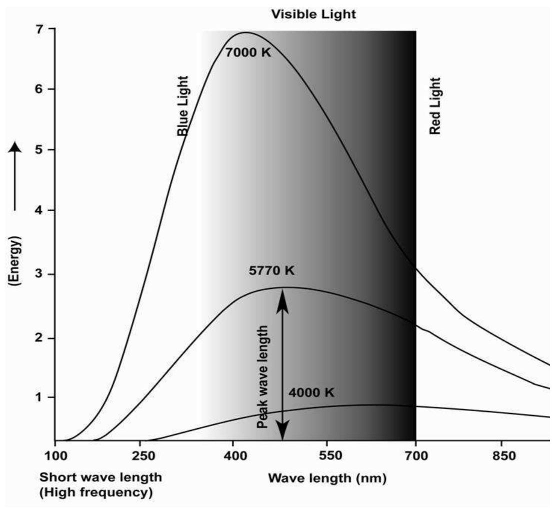

Figure 1

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