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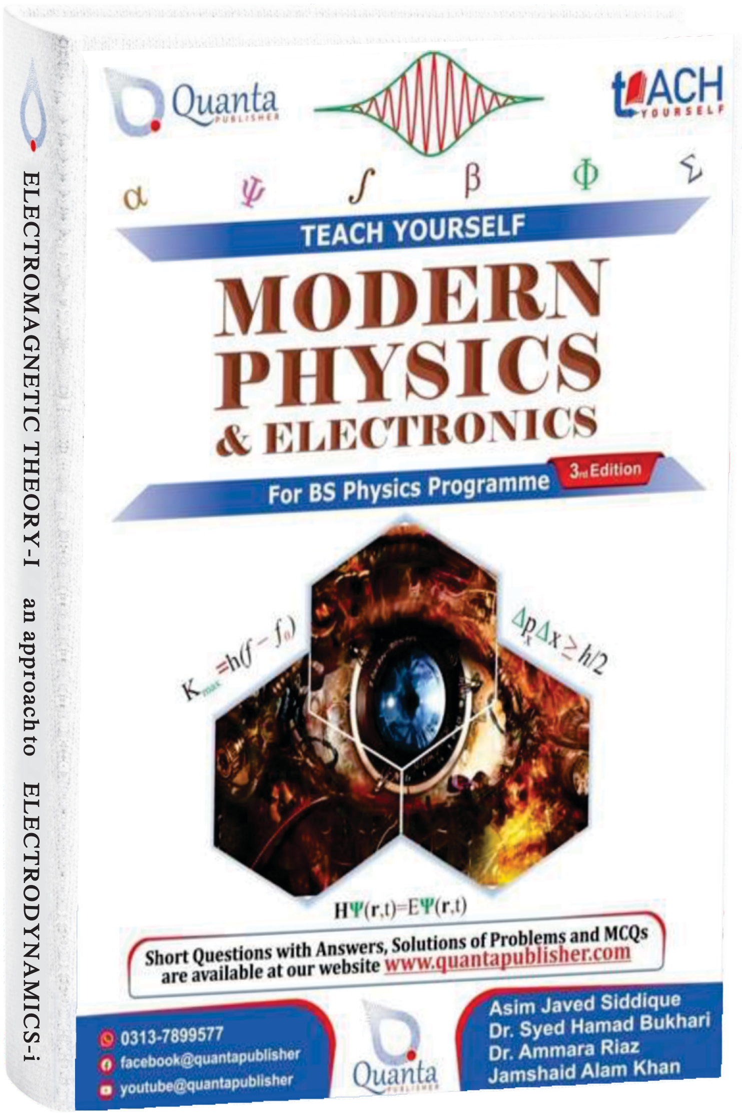

TEACH YOURSELF

MODERN PHYSICS & ELECTRONICS

3rd Edition

For **BS Physics** students of all Pakistani Universities

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Chapter 1

Origins of Quantum Mechanics

THE word quantum comes from the Latin word *quantus*, meaning how much. In physics, a quantum (plural quanta) is the minimum amount of any physical entity (physical property) involved in an interaction. However, mechanics is concerned with the behaviour of physical bodies when subject to motion.
At the end of the 19^{th} century, many scientists believed that they had learned most of what there was to know about physics. In the start of the 20^{th} century, a major revolution shook the world of physics. The reason WHY we need quantum mechanics is indeed the most important question of all the time. Actually, quantum mechanics was developed to solve a very particular problem and that is what we are going to cover in this chapter. This is a pre-paratory chapter in which we summarize experiments and theories, contribute to the genesis of Quantum Mechanics, formulated during the early decades of the century.

1.1 Introduction

Historically, ancient Greek philosophers say that if you took a piece of any material and you cut it into half, then the remaining half should cut into two halves again and that you keep doing it again and again, could you continue doing this forever? **Democritus** says that you could not continue to do that, you will reach a point where you no longer cut into half. The very last piece which will be left indivisible is called an **Atomos**, which mean indivisible in Greek. **Aristotle** says that there is no limit and you can keep doing that till end. For almost 2000 years, Aristotle thinking was considered to be right i.e. there is no building block of matter.

Chapter 2

Wave Particle Duality

2.1 Wave Behavior of Particles

Students introduced to the dual nature of light often find the concept difficult to accept. In the world around us, we are accustomed to regarding such things as baseballs solely as particles and such things as sound waves solely as forms of wave motion. Every large scale observation can be interpreted by considering either a wave explanation or a particle explanation, but in the world of photons and electrons, such distinctions are not as sharply drawn. Even more disconcerting is the fact that, under certain conditions, the things we unambiguously call particles exhibit wave characteristics.

In 1923, in his doctoral dissertation, **Louis de Broglie postulated that because photons have both wave and particle characteristics, perhaps all forms of matter have both properties.** This was a highly revolutionary idea with no experimental confirmation at that time. According to de Broglie, electrons, just like light, have a dual particle-wave nature. Accompanying every electron is a wave (not an electromagnetic wave).

We found that the relationship between the energy and the linear momentum of a photon, which has a rest mass of zero, is $p = E \ c$. We also know that the energy of a photon is $E = hf = hc \quad$. Thus, the momentum of a photon can be expressed as

$$p = \frac{E}{c} = \frac{hc}{c} = \frac{h}{\ } \tag{2.1}$$

From this equation, we see that the photon wavelength can be specified by its momentum: $\ = h \ p$. Louis de Broglie suggested that material particles of momentum p have a characteristic wavelength $\ = h \ p$. Because the momentum of a particle of mass m and speed v is $p = mv$, the **de Broglie wavelength** of that particle is

Chapter 3

Introduction to Quantum Mechanics

3.1 Wavefunction: Another Marvel

In this section, we will build the concept about the symbol that represents the field of a particle. This represents any particle like electron, proton, neutron, photon, etc that we deal at the microscopic level. Generally, it is known as a wavefunction ( ). A wavefunction depends on both position (r) and time (t) coordinates and is denoted as (r t).

Physical Interpretation

Normally, in water wave, we have particles that oscillate, in sound waves we have pressure difference Similarly, What is inside the wavefunction that is waving? or What does represent physically? Interestingly, **wavefunction at a particular time contains all information that anybody at that time can have about the particle.** Also, wavefunction only represents the amplitude of the field and has no direct physical meaning (not measurable). So, the out come of any experiment is not directly depending on , it depends upon ^{2}.

Probabilistic Interpretation

In 1927, Born interpreted ^{2} as the probability density and ^{2} d^{3}r as the probability of finding a particle at time t in the volume element d^{3}r, where ^{2} has the dimensions of [Length] ^{3}. As a result, when discussing quantum effects, it is suitable to use the amplitude of wavefunction , whose square modulus ^{2}, is equal to the intensity of the wave associated with this quantum effect. If we integrate over the entire space, we are certain that the particle is somewhere in it. Thus, the total probability of finding the particle somewhere in space must be equal to one:

$$\boxed{\int_{all\ space} (r\quad t)^2 d^3r = 1} \tag{3.1}$$

Chapter 4

Atomic Physics

4.1 Introduction

All objects emit thermal radiation characterized by a continuous distribution of wavelengths. In sharp contrast to this continuous distribution spectrum is the discrete line spectrum emitted by a low-pressure gas subject to an electric discharge. (Electric discharge occurs when the gas is subjected to a potential difference that creates an electric field larger than the dielectric strength of the gas.) **Observation and analysis of this emitted light is called emission spectroscopy**.

Spectroscopy

The branch of physics which deals with the investigation of wavelengths and intensities of electromagnetic radiations emitted or absorbed by atom is called *Spectroscopy.*

Type of Spectra

1. Continuous spectrum (black body spectrum).
2. Band spectrum (molecular spectrum).
3. Line/discrete spectrum (atomic spectrum such as hydrogen).

When the light from a gas discharge is examined with a spectroscope, it is found to consist of a few bright lines of color on a generally dark background (The lines are due to the collimation of the light through a slit). This discrete line spectrum contrasts sharply with the continuous rainbow of colors seen when a glowing solid is viewed through a spectroscope. Furthermore, the wavelengths contained in a given line spectrum are characteristic of the element emitting the light. The simplest line spectrum is that for atomic hydrogen, and we describe this spectrum in detail. Other atoms exhibit completely different line spectra. Because no two elements have the same line spectrum, this phenomenon represents a practical and sensitive technique for identifying the elements present in unknown

Chapter 5

Nuclear Physics

In present chapter the different properties of the nucleus have been discussed such as mass, volume, density, size, mass defect, binding energy, magnetic moment, angular momentum etc. Before knowing the insight of the nucleus it is necessary to review the idea of atomic models presented by different Scientists with the passage of time. Some of the models are enlisted below.

1. Daltons Atomic Model.

2. J. J Thomsons Model of Atom.

3. Rutherfords Atomic Model.

5.1 Models

Daltons Atomic Model

In 1803, Dalton presented his theory related to atom which was named by **Atomos** meaning indivisible has the following postulates as follows:

All the elements are composed of atoms which cannot be divided further by any means.

All atoms have the same identity of the same element. Atoms of different elements are different in weight and character.

Different atoms of different species can be combined to form a compound like B_2O_3, SiO_2 etc.

These famous postulates have been dominated till the end of 19th century and assumed to be the atom as a neutral. Later as the science developed by different scientists, this theory was discarded that atom cannot be subdivided. Specially, after the discovery of electron by J. J. Thomson in 1897 which revolutionized the world about the structure of atom. So, it was assumed that electron is the basic constituents of all atoms. But it disturbed

Chapter 6

Basic Electronics

6.1 Basic Crystal Structure

Solids

The solids are the forms of matter in which atoms and molecules are strongly bound and maintain definite volume and shape unless changed by applying external forces.

Classification of Solids

On the basis of structure, solids can be classified into two categories:

Crystalline solids Non-crystalline or amorphous solids

Crystalline Solids

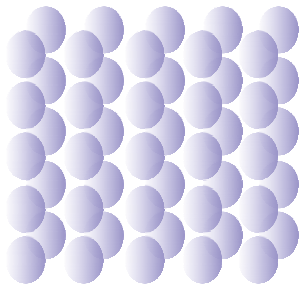
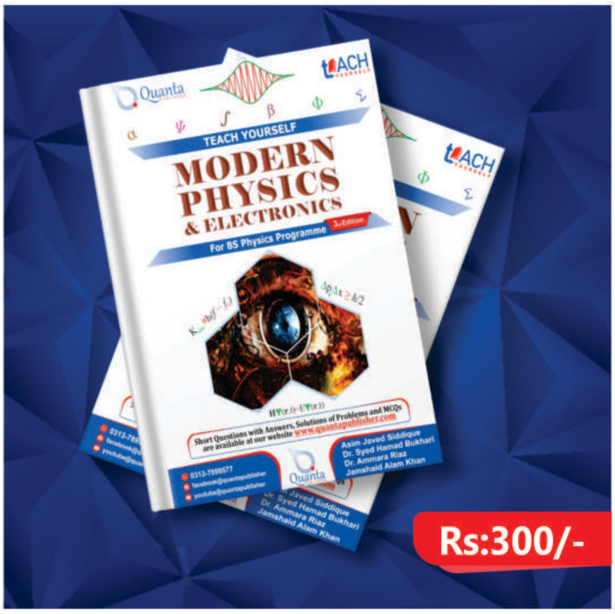


Fig. 6.1. The schematic picture of crystalline solids.

When the constituent atoms of a solid are arranged in a definite, regular and repeated geometric pattern throughout the entire three dimensional network of the crystal, then the solid is called a *Crystalline Solid*. Examples of crystalline solid include diamonds, metals, rock salts, quartz, sugar, ice. Structure of crystals has particular arrangement of particles and primary to understand. This arrangement of particles in a crystalline solid is in a very orderly fashion (see Fig.(6.1)). **These particles are arranged in a repeating pattern of a three-dimensional network. This network is known as a crystal lattice whose smallest unit is a unit cell**. If you see the X-ray of a crystal this distinct arrangement of the unit cells will be clearly visible. The spaces between the atoms are very less due to high intermolecular forces which results high melting and boiling points. The intermolecular force is uniform throughout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