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# New Dimensions of Theories
## Introduction to Quantum System

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***Abstract*—Quantum mechanics, classical mechanics and Theory of relativity are very important theories in the field of science. In this we learn about the main characteristic on the basis of which they are differentiated. Paper is mainly focused on Quantum mechanics with new examples to provide new way of learning and understanding quantum mechanics. It also gives the explanation of the terms used to define quantum system.**

***Keywords*—Quantum Mechanics;Classical Mechanics;Theory of relativity; Formulations;***

## I. Introduction

Theories and formulation are the back bone of science. We use this theories to explain many phenomena that occurs in our surrounding and use formulations to prove those theories. The most famous and important theories are Quantum mechanics, classical and theory of relativity which make other theories more explainable and satisfactory. But due to increase in demand of new formulation and more satisfactory theories we stop focusing on these theories to make them more understandable, due to this whoever wants to learn this theory, face many problems mainly in the usage of technical terms. These days most of the researchers focus on Formulations, which are more complex than theories. No one can understand this formulation without basic understanding of these theories. We can get many materials on internet but all of them use same example due to which many students do not understand these theories and formulation at the beginning.

This paper firstly focus on Quantum mechanics, new examples, terms use to define quantum system and features on the basis of which quantum mechanics is differentiated from relativistic theory and classical theory. Section II provides brief introduction to relativistic theory, quantum theory and classical theory and the feature on the basis of which they differentiate. Section III contains cases and example to make these theories more understandable. Section IV provides introduction about terms used to define quantum system. Section V contains different types of Formulations defined for quantum system and classical system. Section VI deals with the most important questions related to electron duality. Section VII provides the conclusion. Section VIII focus on acknowledgment and references.

## II. Theories and Differentiation

Now assume that the whole universe has been divided into 3 classes on the basis of size. Those objects whose size is very large like planets, satellite, celestial bodies and galaxy relativistic theory is used. But for applying relativistic theory it is also important that the speed of the objects should be comparatively equivalent to the speed of light. After this let us put those objects into class 2 which are on earth and can be seen with eyes or in simple words those objects whose size is greater than microscopic level but smaller than planets. For those objects we use classical mechanics. In class 3 put all those matter whose size is less than microscopic level for that we use quantum theory. At this point we get a basic over view of where to use which theory. But it is not fully true. Classical theory is sometimes use for class 3 and class 1 objects as well.

Now we will see more features of all these theories but before that we will read small introduction.

### A. *Theory Of relativity*

This theory is suggested by Albert Einstein .It considers two most common factor. First is speed, whenever a body is moving with fastest speed comparable to light speed than its mass increases.

Second is Frame of reference: Take an example, Assume 3 persons seating in 3 trains running parallel to each other with different speeds. Whenever anyone see the train on which the other is sitting, he finds that the speed of the train with respect to his train is different when compared to the actual speed of the other train. This happens due to different reference frame. But speed of light is always constant and does not depend on Frame. So the speed of light from the head light of a moving car does not depend on the speed of car.

### B. *Classical Theory*

Classical mechanics deals with the motion of bodies under the influence of forces or with the equilibrium of bodies when all forces are balanced. The central concepts in classical mechanics are force, mass, and motion. Neither force nor mass is very clearly defined by Newton. Mass is a measure of the tendency of a body to resist changes in its state of motion. Forces, on the other hand, accelerate bodies, which is to say, they change the state of motion of bodies to which they are applied. The interplay of these effects is the principal theme of classical mechanics. Although Newton's laws focus on force and mass, three other quantities take special importance because their total amount never changes. These three quantities are energy, linear momentum, and angular momentum.

### C. *Quantum mechanics*

Quantum mechanics is the branch of physics relating to very small. Quantum mechanics, science dealing with the behavior of matter and light on the atomic and subatomic scale. It attempts to describe and account the properties of molecules and atoms and their constituent's electrons, protons, neutrons, and other more esoteric particles such as quarks and gluons.

### D. *Features of Theories*

1) Size

We have already classified the objects on the basis of size and also know what theory is used for different objects. But

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there is overlap between classical theory and relativistic theory for some objects, for simplicity we will put those objects in class 32 and call overlap region RC-region. Same way classical theory and Quantum theory also have some overlapping objects let us put them under class12 and call this overlap region QC-region. Remember that we cannot use quantum physics for larger objects and relativist theory for microscopic objects excluding on mass if object speed is equivalent to speed of light.

2) Speed

Speed of an object is also an important phenomena on which theories are classified. In most cases when speed of the object is equivalent to speed of light we use theory of relativity. On the other hand no specific limit for quantum mechanics and classical mechanics.

3) Physical quantities on which results are produced

In every experiment we first have to know what are we finding so that we can conclude the result. For example to find the average of values we have to know total number of values and what the value is. Same way theories are used to find the variables. Here we learn the physical variables on which theories work.

Relativistic Theory considers Space and time for calculation to get result.

Classical Theory consider Force, mass and acceleration for producing the result.

Quantum Theory consider number of particles, radiation at atomic scale and probability of occurrences of matter.

## III. EXAMPLE

In this section we see some examples to understand the quantum mechanics.

Case1: Take an example of burning candle .According to classical theory you see a flame which has different color at different position. Classical theory cannot explain why the color of flame is different. Same way if you heat an iron rod it shows different color at different temperature.

Fig 1: different color of flame at different position and change in color of iron rod at different temperature.

To find the solution of this question Quantum physics came into existence. In this we consider flame is not continuous but as group of particles called photons. Each photon has its own frequency and energy. Due to different frequencies it emanates different color. Same way when an iron rod is heated it produce photon at different frequencies due to which it shows different color.

Case 2: Take another example of quantum physics. In quantum physics we see a matter in the form of group of particles which make an entity. This example is for basic understanding, it has no relation with actual physics. Let us consider a glass of water according to classical physics the glass contains water. But according to quantum physics glass contain molecules of water. What actually we do in quantum mechanics is we see everything in the form of particles or packets which have its own existence. For example in classical mechanics House is an entity while in quantum mechanics we see the number of bricks use to make that house.

Case 3 Quantum mechanics also provides the answer to the question why the electron eject from material surface at particular frequency. Let us understand this, assume to break a stone you need 10N force or above. This means if you give force less than 10N then it is a waste does not matter how many time you try. Same way every electron is bound in his orbit and require a minimum energy called threshold energy. Until you do not provide that much energy to the electron it will not come out. Classical mechanics cannot provide the answer of this question while quantum mechanics provides the answer.

## IV. TERMS USE TO DEFINE QUANTUM SYSTEM

Every system has its own language to define its properties same way quantum system has its own. Here we see the definition uses for quantum system. We have already learned how the quantum theory is applied at atomic level or sub atomic level for this we take an atom. We know that an atom consists of nucleus and electrons. Electrons rotate around the nucleus in fixed orbit.

### *A. Quantum potential well*

It is the potential well created between the voltage difference of nucleus and the electron orbit at infinity. But in quantum potential well we see potential as discrete form rather than continuous form.

### *B. Quantum Number*

By Schrödinger's picture, each electron has four properties. On this properties we differentiate atoms and create periodic table.

a) The first property describing the orbital is called the principal quantum number (n), which is the same as in Bohr's model. n denotes the energy level of each orbital. The possible values for n are integers: n=1, 2, 3...

b) The next quantum number, the azimuthal quantum number, denoted by l, describes the shape of the orbital. The shape is a consequence of the angular momentum of the orbital. The angular momentum represents the resistance of a spinning object to speeding up or slowing down under the influence of external force. The azimuthal quantum number represents the orbital angular momentum of an electron around its nucleus. The possible values for l are integers from 0 to n − 1:

The shape of each orbital has its own letter as well. The first shape is denoted by the letter s (a mnemonic being "sphere"). The next shape is denoted by the letter p and has the form of a dumbbell. The other orbitals have more complicated shapes, and are denoted by the letters d, f, and g.

c) The third quantum number, the magnetic quantum number, describes the magnetic moment of the electron, and is denoted by ml (or simply m). The possible values for ml are

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integers from −l to l. The magnetic quantum number measures the component of the angular momentum in a particular direction. The choice of direction is arbitrary, conventionally the z-direction is chosen.

d) The fourth quantum number, the spin quantum number (pertaining to the "orientation" of the electron's spin) is denoted by s, with values +1⁄2 or −1⁄2.

Let us understand this quantum states and the need for this quantum number. Assume you have 6 electrons and you have to place them into the orbits. How you are going to place them. During the placement we have to ensure that no two electrons have same set of quantum state this principle is called Pauli Exclusion Principle. For this we start from n=1, we get l=0, m=0, s=-1/2 and +1/2 now we can see the 2 electrons can be put in first orbit which have different spin. For m=0 shows that orbit shape is spherical. After placing two electrons we have 4 electrons left. now for n=2 orbit, for this orbit l=0,1.now we can see l has two value meaning m=0 for l=0 and m=-1,0,1 for l=1.and s= -1/2,+1/2 for each pair of electron. According to this placement of electron we create the modern periodic table.

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### C. *Quantum State*

As we learned in previous topic each electron has a unique set of quantum number, combining this quantum number make a quantum state. We also see in many cases when we talk about quantum system state we actually talk about this quantum number. Quantum system consist of different states sometimes we consider the position of particle in quantum wall so it is up to us which quantum state we are taking to produce the result.

### D. *Probability*

In quantum physics we talk in terms of probability. Because at this level finding the actual value is not possible that the reason we focus on number of occurrence of an event or particle so that we can find the result and compare it with the other. Commonly use variable on which we produce result are number of particle in a quantum well, Potential difference at particular point etc.

In the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## V. Formulation

Before starting this section we will first learn what formulation is and why we do formulation in science.

Formulation is a way to represent any theory into mathematical equation. Through formulation we can find the result in quantitative manner on the other hand theories provide qualitative result only. Now let's understand it, assume an experiment is conducted in which you represent the result saying it is good. But in this result we cannot analyze the result while on the other hand if we represent result as 90% of work is done than we get better understanding of the result and status of experiment. Same way a formulation of a theory gives the result in more quantitative way rather than theoretical understanding. Same way many researcher also provide many formulation to get the result of Quantum system, Classical system and theory of relativity. At initial stage it looks like they are different but they all provide same result at the end. Now in the end we see the different types of formulation for different systems

### A. *Quantum mechanics*

- The matrix formulation (Heisenberg)
- The wave function formulation (Schrödinger)
- The path integral formulation (Feynman)
- Phase space formulation (Wigner)
- Density matrix formulation
- Second quantization formulation
- Variation formulation
- The pilot wave formulation (de Broglie–Bohm)
- The Hamilton–Jacobi formulation

For detail knowledge about this formulation you can check this paper [1]

### B. *classical mechanics formulations*

- Newtonian
- Lagrangian
- Hamiltonian
- Hamilton's principle ~called by Feynman and Landau ''the principle of least action''!
- The Maupertuis principle of least action ~also associated with the names of Euler, Lagrange, and Jacobi!
- Least constraint (Gauss)
- Least curvature (Hertz)
- Gibbs–Appell
- Poisson brackets
- Lagrange brackets
- Liouville
- Hamilton–Jacobi

For detail knowledge about the formulation you can check this paper [2]

## VI. Electron Duality

In this section we discuss about electron duality and what is this.

Electron duality state that electron shows dual nature, means in some cases electron shows wave type property and in some cases its show particle type property. Let us understand it those matter which shows the properties of Interference, diffraction and polarization are called waves. On the other hand those matter which shows photoelectric effect, called particle. In case of electrons, it shows both particle nature as well as wave nature. Let us understand in detail in case of wave when it is pass throw two slit of same width at a small distance with each other it creates an interference pattern at another side of slit. For more detail about interference pattern check [3].same way when a normal particle fire to the slit some particles may pass from gaps or stop by the boundaries. But in case of electron when a beam of electron passes through the two slits it shows the interference pattern. So from this experimental evidence a question occurs that electron is wave or particle. This question still exists and many researchers are trying to find the answer. While Louis de Broglie in 1929 won the Nobel Prize in Physics for his prediction that matter acts as a wave, made in his 1924 PhD thesis. Just as light has both wave-like and particle-like properties, matter also has wave-like properties. Still we are searching for formulation to represent dual particle nature of electron.

## VII. CONCLUSIONS

Quantum mechanics, classical mechanics and theory of relativity are most important theories in field of science. We learned about these theories and on the basis of which they are differentiated. We also learned about different examples related to quantum mechanics and know about terms which are used to define the quantum system. At the end we see the biggest question about electron duality and know about wave-particle duality.

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