
UNIT 2 QUANTUM MECHANICS

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2.0 OBJECTIVES

- To introduce the students to some of the key ideas of quantum mechanics.
- To show the weirdness of the theory.
- To indicate how successful the theory is, though most people do not understand it.

2.1 INTRODUCTION

Two of the most revolutionary theories of 20th century were Theory of Relativity and Quantum Mechanics. Theory of relativity is a deviation from Newtonian Mechanics (or common sense.). The deviations were not discovered until this Century because they are only noticeable at high speeds and under very intense gravitational fields. There is another 20th Century idea that also violates Newtonian Mechanics. This is called Quantum Mechanics (Tal 2009).

In fact, Quantum mechanics is one of the major revolutions in 20th century Physics. It is probably the closest science has come to a fundamental description of the underlying nature of reality. And yet it is totally bizarre—it flies in the face of all our intuition and common sense. It sounds more like science fiction, or a poorly written fantasy, than notions which serious scientists would entertain (Felder & Felder 1998). So one of the best scientists of last century, R. Feynman has this to say: “It is often stated that of all the theories proposed in this century, the silliest is quantum theory. Some say that the only thing that quantum theory has going for it, in fact, is that it is unquestionably correct.” In this unit, we want to study the basic notions of it, its strange (or weird) character, its practical implications and we conclude with some remarks on human intuition.

2.2 THE STORY OF THE ATOM

In this section we will give a taste of the strange and fascinating world of the atom. We will keep it as descriptive and not mathematical. The Ancient Greeks proposed that matter could not be divided indefinitely. They speculated that matter

was made up of units called atoms. The word comes from a Greek word meaning single item or a portion. They assumed that atoms were solid, different characteristics of substances being determined by the different shapes that atoms had. This atomic idea never really became popular (Tal 2009).

During the 16th Century, chemists worked out that behaviour of gases. If they doubled the volume of a gas, its pressure halved. If they halved its volume, its temperature doubled. It was also found that chemical reactions always took place in fixed ratios. For example one volume of oxygen always combined with two volumes of hydrogen to produce water (assuming the gases were at the same temperature and pressure). Results like these lead to the idea of atoms. The Atomic Theory was surely the best way to explain these and other phenomena. (Tal 2009)

When the idea of elements came, it was assumed that different elements had different atoms. John Dalton showed that each element had an atom that differed in weight (correctly, mass) to other atoms. So now we say that a Carbon atom has a relative mass of 12, Oxygen has one of 16. The unit is the Hydrogen atom, the lightest of all the atoms. During the middle of the 19th Century, James Maxwell explained the gas laws by applying statistics to the random motions of atoms. He showed that when you heat a gas you make its molecules go faster. These strike the surface of the container with more force, thus increasing the gas pressure. To keep the pressure the same the volume has to be increased. Atoms were now taken for granted and treated as featureless spheres (i.e. little balls). (Tal 2009)

At this point the idea that atoms were featureless spheres was overturned by several discoveries made towards the end of the 19th Century. Firstly, there were experiments in electricity and magnetism which indicated the existence of particles with less mass than the Hydrogen atom. The electron was the most famous of these. Secondly, atoms were found to be more complex than previously thought when radioactivity was discovered. Atoms were throwing out bits and changing to other atoms; atoms could take and give an electric charge.

From various observations and experiments it was eventually decided that an atom was made up of three particles (Tal 2009):

- Protons - these were charged with electricity that was positive and contained most of the mass of atoms.
- Electrons - these were very light particles ($1/1800$ th the mass of a Hydrogen atom.) with a negative electric charge exactly equal to the charge on a proton.
- Neutrons - neutral particles with a mass similar to protons but with no charge.

In an atom, the protons and neutrons were in the central regions of the atom (called the nucleus) while the electrons revolved around at high speed. It was the outer electrons that interacted when atoms reacted chemically with other atoms. It was these electrons that were involved in electrical effects. It was the number of protons that determined how many electrons there were (they had to be the same). This number (called the Atomic Number) determined how the atom behaved, i.e. what element it was. Hydrogen atoms have 1 proton and 1 electron, Oxygen has 8 of each, Uranium has 92 of each. The electrons were held in orbit by electric attraction (positive and negative attract), much as the planets were held in orbit around the sun by the attractive force of gravity.

The above description of the atom is the Newtonian (or Classical) description. It is possible to picture it and it makes sense. Unfortunately, this description violates Maxwell’s Laws of Electromagnetism. Maxwell’s Laws of Electromagnetism were very powerful tools. However they could not explain how an atom could be stable. Under those laws, an electrically charged object (like an electron) that was changing direction (in orbit around the nucleus of an atom) should be radiating energy away until it spiralled into the nucleus. Clearly this does not happen. Atoms are stable. Furthermore, there were a few other observations about atoms that were not quite right (Tal 2009).

Of course, atoms did absorb and radiate energy. The problem was that this process was strictly controlled. Atoms only absorbed specific wavelengths of energy. Sodium, for example, radiated a lot of yellow light (hence its use in street lamps), Potassium radiated lilac (hence the colour of most fireworks). This was a major flaw in the physics of the turn of the century. Physics had other problems - phenomena that didn’t work as predicted: the way a hot, glowing body radiated energy at a given temperature (the Black Body Problem); the way metals produced electricity when light shone on them (the Photoelectric Effect); the way atoms decayed when they were radioactive. Something was wrong with the state of Physics. What was needed was a revolution in Physics. Unlike the onset of relativity which was the brainchild of one man, this new idea would spawn from many minds – in fact the best minds of those days.

Check Your Progress I

Note: Use the space provided for your answers.

1) “Some say that the only thing that quantum theory has going for it, in fact, is that it is unquestionably correct.” Give your comments.

2) Describe the structure of an atom?

2.3 INTRODUCING QUANTUM MECHANICS

Isaac Newton thought that light was a stream of particles; Thomas Young thought it was a wave. Most people at the turn of the century thought of light as a wave. In 1900 Max Planck found that he could explain the way hot bodies radiate

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energy only if he assumed that energy occurred as packets. He assumed that his equations were simply tricks with the mathematics and called these packets of energy quanta. The equations were useful but the underlying ideas were not taken seriously. In 1905, Albert Einstein published three scientific papers, any one of which was the mark of a genius. The first was Part One of his Theory of Relativity. The second proved the existence of atoms from direct observations (an effect called Brownian Motion).

The third paper is the relevant one for this essay. In this paper, he applied Planck's quantum idea of 1900 to explain the Photoelectric Effect. These quanta were now being utilised to explain two previously unexplainable phenomena. However, if quanta were real, was light a wave or a particle? It was as if in some experiments (refraction, diffraction) light was clearly a wave; in others (black body radiation, the photoelectric effect) it was a particle. This effect was strange and was known as wave-particle duality (Tal 2009).

In 1912, Louis de Broglie, suggested that if energy could behave as both particles and waves, perhaps matter could also. He nearly didn't get his PhD for that ridiculous suggestion. He produced the mathematics and predicted that under the right conditions a beam of electrons (clearly matter made of particles) might show wave properties. Surprisingly, when the experiment was performed, a beam of electrons was found to diffract just like a wave would have done. That was it. It looked like energy and matter could both exhibit wave-particle duality. It appeared that a moving particle had a wavelength. Neils Bohr decided to work out the wavelength of an electron moving around the nucleus of an atom. He found that for an electron to have a stable orbit, the orbit had to include a whole-number of the electron's wave. Orbits that include fractions of waves were impossible so the electron could not inhabit them. In other words, an electron could have a stable orbit, so that it would not lose energy and spiral in to the nucleus. If an electron absorbed or radiated energy, it would do so in discreet amounts so that it would move to another stable orbit. The analogy is a staircase. You can only stand on the steps, not in the region between steps.

So these quantum ideas explained two things. Why atoms were stable and why atoms absorbed or emitted energy in selected wavelengths. Bohr used his ideas to predict what energy could be radiated from different atoms. His theories corresponded with observation. In 1925, Erwin Schrodinger and Werner Heisenberg separately worked out the mathematics of Quantum Mechanics. Using this new theory, scientists could understand the behaviour of atoms and subatomic particles. The wave-particle duality concept is true for both matter and energy. The 'position' of a particle like an electron is given by a probability. Electrons exist in energy states. When they absorb energy, they absorb a whole number of quanta, disappear, appearing at a different energy state. Gone is the idea of little ball-like particles. The orbit of an electron is a cloud of probability around the nucleus (Tal 2009).

Another quantum effect is the famous Uncertainty Principle. This implies that there is a built-in uncertainty in the Universe. It is possible for something to be created out of nothing, given enough time. On a subatomic level it is impossible to pinpoint things down to an infinite precision. And not because of any technological failings: this is a constraint of the Universe itself. A zero energy is impossible since it would be a precise state. This is the reason that nothing can

be cooled below -273 degrees C (Absolute Zero). An atom must retain at least one quantum of energy and this keeps it from cooling below Absolute Zero. This means that nothing can ever be at rest. Quantum effects are not noticeable in the macro world. They only become important as one approaches the dimensions of the atom. (Tal 2009).

Fast and Young

A tumultuous series of events occurred within the three-year period from January 1925 to January 1928 culminating in quantum revolution. We list some of them main events:

- Wolfgang Pauli proposed the exclusion principle, providing a theoretical basis for the Periodic Table.
- Werner Heisenberg, with Max Born and Pascual Jordan, discovered matrix mechanics, the first version of quantum mechanics. The historical goal of understanding electron motion within atoms was abandoned in favour of a systematic method for organizing observable spectral lines.
- Erwin Schrödinger invented wave mechanics, a second form of quantum mechanics in which the state of a system is described by a wave function, the solution to Schrödinger's equation. Matrix mechanics and wave mechanics, apparently incompatible, were shown to be equivalent.
- Electrons were shown to obey a new type of statistical law, Fermi-Dirac statistics. It was recognized that all particles obey either Fermi-Dirac statistics or Bose-Einstein statistics, and that the two classes have fundamentally different properties.
- Heisenberg enunciated the Uncertainty Principle.
- Paul A.M. Dirac developed a relativistic wave equation for the electron that explained electron spin and predicted antimatter.
- Dirac laid the foundations of quantum field theory by providing a quantum description of the electromagnetic field.
- Bohr announced the complementarity principle, a philosophical principle that helped to resolve apparent paradoxes of quantum theory, particularly wave-particle duality.

The principal players in the creation of quantum theory were very young. In 1925 Pauli was 25 years old, Heisenberg and Enrico Fermi were 24, and Dirac and Jordan were 23. Schrödinger, at age 36, was a late bloomer. Born and Bohr were older still, and it is significant that their contributions were largely interpretative. The profoundly radical nature of the intellectual achievement is revealed by Einstein's reaction. Having invented some of the key concepts that led to quantum theory, Einstein rejected it. His paper on Bose-Einstein statistics was his last contribution to quantum physics and his last significant contribution to physics. That a new generation of physicists was needed to create quantum mechanics is hardly surprising. Lord Kelvin described why in a letter to Bohr congratulating him on his 1913 paper on hydrogen. He said that there was much truth in Bohr's paper, but he would never understand it himself. Kelvin recognized that radically new physics would need to come from unfettered minds. In 1928 – just within a span of three years - the revolution was finished and the foundations

of quantum mechanics were essentially complete. The main actors were very young and energetic minds in their 20s (Kleppner and Jackiw).

Controversy and Confusion

Alongside these advances, however, fierce debates were taking place on the interpretation and validity of quantum mechanics. Foremost among the protagonists were Bohr and Heisenberg, who embraced the new theory, and Einstein and Schrödinger, who were dissatisfied. To appreciate the reasons for such turmoil, one needs to understand some of the key features of quantum theory, which we summarize here. (Kleppner & Jackiw 2000)

Fundamental description: the wave function. The behavior of a system in quantum mechanics is described by Schrödinger's equation. The solutions to Schrödinger's equation are known as wave functions. The complete knowledge of a system is described by its wave function, and from the wave function one can calculate the possible values of every observable quantity. The probability of finding an electron in a given volume of space is proportional to the square of the magnitude of the wave function. Consequently, the location of the particle is "spread out" over the volume of the wave function. The momentum of a particle depends on the slope of the wave function: The greater the slope, the higher the momentum. Because the slope varies from place to place, momentum is also "spread out." The need to abandon a classical picture in which position and velocity can be determined with arbitrary accuracy, in favor of a blurred picture of probabilities, is at the heart of quantum mechanics (Kleppner & Jackiw 2000).

Waves can interfere. The heights of waves can add or subtract depending on their relative phase. Where the amplitudes are in phase, they add; where they are out of phase, they subtract. If a wave can follow several paths from source to receiver, as a light wave undergoing two-slit interference, then the illumination will generally display interference fringes. Particles obeying a wave equation will do likewise, as in electron diffraction. The analogy seems reasonable until one inquires about the nature of the wave. A wave is generally thought of as a disturbance in a medium. In quantum mechanics there is no medium, and in a sense there is no wave, as the wave function is fundamentally a statement of our knowledge of a system (Kleppner & Jackiw 2000).

Questions such as what a wave function "really is" and what is meant by "making a measurement" were intensely debated in the early years. By 1930, however, a more or less standard interpretation of quantum mechanics had been developed by Bohr and his colleagues, the so-called Copenhagen Interpretation. The key elements are the probabilistic description of matter and events, and reconciliation of the wavelike and particle-like natures of things through Bohr's principle of complementarity. Einstein never accepted quantum theory; he and Bohr debated its principles until Einstein's death in 1955. Nevertheless, the nature of quantum theory continues to attract attention because of the fascination with what is sometimes described as "quantum weirdness." (Kleppner & Jackiw 2000).

Differences from Classical Physics

Now that we have some idea of the basics of quantum mechanics, we can try to compare it with classical mechanics. The main difference of the new theory from classical physics could be summed up as follows:

- 1) In classical mechanics a particle can have any energy and any speed. In quantum mechanics these quantities are quantized. This means that a particle in a quantum system can only have certain values for its energy, and certain values for its speed (or momentum).
- 2) Newton’s Laws allow one, in principle, to determine the exact location and velocity of a particle at some future time. Quantum mechanics, on the other hand, only determines the probability for a particle to be in a certain location with a certain velocity at some future time. The probabilistic nature of quantum mechanics makes it very different from classical mechanics.
- 3) Quantum mechanics incorporates what is known as the “Heisenberg Uncertainty Principle.” This principle states that one cannot know the location AND velocity of a quantum particle to infinite accuracy. The better you know the particle’s location, the more uncertain you must be about its velocity, and vice versa. In practice, the level of uncertainty that is required is so small that it is only noticeable when you are dealing with very tiny things like atoms. This is why we cannot see the effects of the Uncertainty Principle in our daily lives.
- 4) Quantum mechanics permits what are called “superpositions of states”. This means that a quantum particle can be in two different states at the same time. For instance, a particle can actually be located in two different places at one time. This is certainly not possible in classical mechanics.
- 5) Quantum mechanical systems can exhibit a number of other very interesting features, such as tunnelling and entanglement. These features also represent significant differences between classical and quantum mechanics, although they will not be as important in our discussion of quantum chaos. (Timberlake 2010)

That is a pretty brief introduction to the ideas of quantum mechanics and many important features have been skipped. But the ideas presented above should make it clear that quantum mechanics is very different from classical (Newtonian) mechanics.

Check Your Progress III

Note: Use the space provided for your answer

1) Why is it that most of the founders of quantum mechanics were very young?

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2) Give some significant differences between classical and quantum mechanics?

2.4 WEIRDNESS OF QUANTUM MECHANICS

As already noted, the field of quantum mechanics concerns the description of phenomenon on small scales where classical physics breaks down. The biggest difference between the classical and microscopic realm, is that the quantum world cannot be perceived directly, but rather through the use of instruments. And a key assumption to quantum physics is that quantum mechanical principles must reduce to Newtonian principles at the macroscopic level (there is a continuity between Quantum and Newtonian Mechanics).

Quantum mechanics was capable of bringing order to the uncertainty of the microscopic world by treatment of the wave function with new mathematics. Key to this idea was the fact that relative probabilities of different possible states are still determined by laws. Thus, there is a difference between the role of chance in quantum mechanics and the unrestricted chaos of a lawless Universe. Every quantum particle is characterized by a wave function. In 1925 Erwin Schrodinger developed the differential equation which describes the evolution of those wave functions. By using Schrodinger equation, scientists can find the wave function which solves a particular problem in quantum mechanics. Unfortunately, it is usually impossible to find an exact solution to the equation, so certain assumptions are used in order to obtain an approximate answer for the particular problem.

However, some of its findings and principles are distinctly counter-intuitive and fiendishly difficult to explain in simple language, without resorting to complex mathematics way beyond the comfort level of most people (myself included.). This situation is not helped by the fact that the “theory” is largely a patchwork of fragments accrued over the last century or so, that some elements of it are still not well understood by the scientists themselves, and that some of the bizarre behaviour it predicts appears to fly in face of what we have come to think of as common sense.

Richard Feynman, winner of the 1965 Nobel Prize for Physics and arguably one of the greatest physicists of the post-war era, is unapologetically frank: “I think I can safely say that nobody understands quantum mechanics”. Niels Bohr, one the main pioneers of quantum theory, claimed that: “Anyone who is not shocked by quantum theory has not understood it.” (UP 2001)

Below we give two implications of quantum mechanics that makes it weird or strange.

Schrodinger's Cat

In 1935 Schrodinger, who was responsible for formulating much of the wave mechanics in quantum physics, published an essay describing the conceptual problems in quantum mechanics. A brief paragraph in this essay described the, now famous, cat paradox.

One can even set up quite ridiculous cases where quantum physics rebels against common sense. For example, consider a cat is penned up in a steel chamber, along with the following diabolical device (which must be secured against direct interference by the cat). In the device is a Geiger counter with a tiny bit of radioactive substance, so small that perhaps in the course of one hour only one of the atoms decays, but also, with equal probability, perhaps none. If the decay happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The wave function for the entire system would express this by having in it the living and the dead cat mixed or smeared out in equal parts (UP 2001).

It is typical of these cases that an indeterminacy originally restricted to the atomic domain becomes transformed into macroscopic indeterminacy, which can then be resolved by direct observation. That prevents us from so naively accepting as valid a "blurred model" for representing reality. In itself it would not embody anything unclear or contradictory. There is a difference between a shaky or out-of-focus photograph and a snapshot of clouds and fog banks. We know that superposition of possible outcomes must exist simultaneously at a microscopic level because we can observe interference effects from these. We know (at least most of us know) that the cat in the box is dead, alive or dying and not in a smeared out state between the alternatives. When and how does the model of many microscopic possibilities resolve itself into a particular macroscopic state? When and how does the fog bank of microscopic possibilities transform itself to the blurred picture we have of a definite macroscopic state. That is the collapse of the wave function problem and Schrodinger's cat is a simple and elegant explanation of that problem (UP 2001).

Conclusion from experiment of the Schroedingers cat:

- The paradox is phrased such that a quantum event determines if a cat is killed or not
- From a quantum perspective, the whole system state is tied to the wave function of the quantum event, i.e. the cat is both dead and alive at the same time
- The paradox in some sense is not a paradox, but instead points out the tension between the microscopic and macroscopic worlds and the importance of the observer in a quantum scenario
- Quantum objects exist in superposition, many states, as shown by interference
- The observer (or measurement) collapses the wave function

Quantum tunnelling refers to the phenomena of a particle’s ability to penetrate energy barriers within electronic structures. The scientific terms for this are: Wave-mechanical tunnelling, Quantum-mechanical tunnelling and the Tunnel effect. Quantum tunnelling was developed from the study of radioactivity, which was discovered in 1896 by Henri Becquerel. It is the study of what happens at the quantum scale. This process cannot be directly perceived, so much of its understanding is shaped by the macroscopic world, which classical mechanics can adequately explain. Particles in that realm are understood to travel between potential barriers as a ball rolls over a hill; in our world, if the ball does not have enough energy to surmount the hill, it comes back down. Classical mechanics predicts that particles that do not have enough energy to climb the hill, it will not be able to reach the other side. In quantum mechanics, these particles can, with a very small probability, tunnel to the other side, thus crossing the barrier.

The reason for this difference comes from the treatment of matter in quantum mechanics as having properties of waves and particles. The wave function of a particle summarizes everything that can be known about a physical system. Therefore, problems in quantum mechanics centre around the analysis of the wave function for a system. Using mathematical formulations of quantum mechanics, such as the Schrödinger equation, the wave function can be solved for. This is directly related to the probability density of the particle’s position, which describes the probability that the particle is at any given place. In the limit of large barriers, the probability of tunnelling decreases for taller and wider barriers. Hence, the probability of a particle on the other side is non-zero, which means that cross the high barrier sometimes. And experimentally it is also verified.

2.5 PRACTICAL VALUE OF QUANTUM MECHANICS

The equations developed by Heisenberg, Schrödinger and their colleagues give a glimpse into the nature of reality, but that’s not all. They are also essential tools of modern work in key areas of practical technology—including the electronics you are using to read this text. Thousands of physicists use the equations of quantum mechanics every day to understand and improve computer components, metals, lasers, the properties of chemicals, and on and on. Many important physical effects, from fluorescent lights to the shape of a snowflake, cannot be understood at all without quantum mechanics.

Even the Uncertainty Principle isn’t “merely” philosophy: it predicts real properties of electrons. Electrons jump at random from one energy state to another state which they could never reach except that their energy is momentarily uncertain. This “tunnelling” makes possible the nuclear reactions that power the sun and many other processes. Physicists have put some of these processes to practical use in microelectronics. For example, delicate superconducting instruments that use electron tunnelling to detect tiny magnetic fields are enormously helpful for safely scanning the human brain.

Quantum theory is used in a huge variety of applications in everyday life, including lasers, CDs, DVDs, solar cells, fibre-optics, digital cameras, photocopiers, bar-code readers, fluorescent lights, LED lights, computer screens, transistors, semi-

conductors, super-conductors, spectroscopy, MRI scanners, lasers, super-conducting devices, etc. By some estimates, over 25% of the GDP of developed countries is directly based on quantum physics. It even explains the nuclear fusion processes taking place inside stars. Thus the effects of quantum mechanics are important in all branches of science. Quantum Mechanics is used to understand phenomena like radioactivity, chemical bonding, semi-conductors, solid-state micro-chips, electronics, sub-atomic physics, radiation from black holes, and many others (Tal 2009).

2.6 FINAL REMARKS ON HUMAN INTUITION

In spite of its weirdness, we have a theory which accounts for all of our experimental results. It correctly predicts the results of double slit experiments with photons or electrons, and it correctly predicts that in the case of normal light beams or particles. In fact, thousands of other experiments have been performed since quantum mechanics was developed, and they have continually supported its predictions to a staggering level of accuracy. This theory seems to apply to every process occurring between any kinds of matter or energy in the universe (Felder & Felder 1998).

No one really understands this theory of quantum mechanics. But Quantum mechanics can be used to successfully predict experimental results. So quantum mechanics leads to new ways of looking at existence and reality. The modern view of quantum mechanics states that Schrodinger’s cat, or any macroscopic object, does not exist as super positions of existence due to de-coherence. A pristine wave function is coherent, i.e. undisturbed by observation. But Schrodinger’s cat is not a pristine wave function it is constantly interacting with other objects, such as air molecules in the box, or the box itself. Thus a macroscopic object becomes de-coherent by many atomic interactions with its surrounding environment.

Decoherence explains why we do not routinely see quantum super positions in the world around us. It is not because quantum mechanics intrinsically stops working for objects larger than some magic size. Instead, macroscopic objects such as cats and cards are almost impossible to keep isolated to the extent needed to prevent de-coherence. Microscopic objects, in contrast, are more easily isolated from their surroundings so that they retain their quantum secrets and quantum behaviour (Uorgaon 2011).

It doesn’t seem to make sense. But another school of thought says, why should it make sense? After all, humans evolved in a world of “normal” objects. And we developed a facility called “intuition” that helped us survive in that world by helping us predict the effects of our actions. That physical intuition was, and is, a great asset. But perhaps it shouldn’t be too surprising that it becomes a liability when we try to apply it to areas that we didn’t evolve for. Quantum mechanical laws generally only have measurable effects when applied to things that are too small to see, so we never evolved an understanding of them, so they seem bizarre (Felder & Felder 1998).

In fact, at roughly the same time that quantum mechanics first began to suggest that *very small* things defy our intuition, Einstein was proposing his special theory of relativity which shows that *very fast* things defy our intuition; and then his

general theory of relativity, which concerns the odd behaviour of *very big* things (Felder & Felder 1998). It seems that, more and more, the only way to understand the world is to apply the math, and stop trying to “understand” what’s actually going on. If you look at it like this, it seems that quantum physics is not weird and incomprehensible because it describes something completely different from everyday reality. It is weird and incomprehensible precisely because it describes the world we see around us-past, present, and future.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is the significance of quantum tunnelling?

2) Is quantum mechanics practical?

2.7 LET US SUM UP

In this unit we have tried to understand the weird character of quantum mechanics, one of the most successful scientific theories. It radically changes the way we look at reality.

2.8 KEY WORDS

De-coherence	: In quantum mechanics, quantum de-coherence is the mechanism by which quantum systems interact with their environments to exhibit probabilistically additive behaviour
Quantum tunnelling	: It refers to the phenomena of a particle’s ability to penetrate energy barriers within electronic structures. The scientific terms for this are Wave-mechanical tunnelling, Quantum-mechanical tunnelling and the Tunnel effect.
Quantum	: A discrete quantity of energy proportional in magnitude to the frequency of the radiation it

represents. It is the smallest amount of a physical quantity that can exist independently, especially a discrete quantity of electromagnetic radiation

Schrödinger’s equation : An equation describing the state and evolution of a quantum mechanical system, given boundary conditions. Different solutions to the equation are associated with different wave functions, usually associated with different energy levels. This equation is fundamental to the study of wave mechanics.

2.9 FURTHER READINGS AND REFERENCES

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