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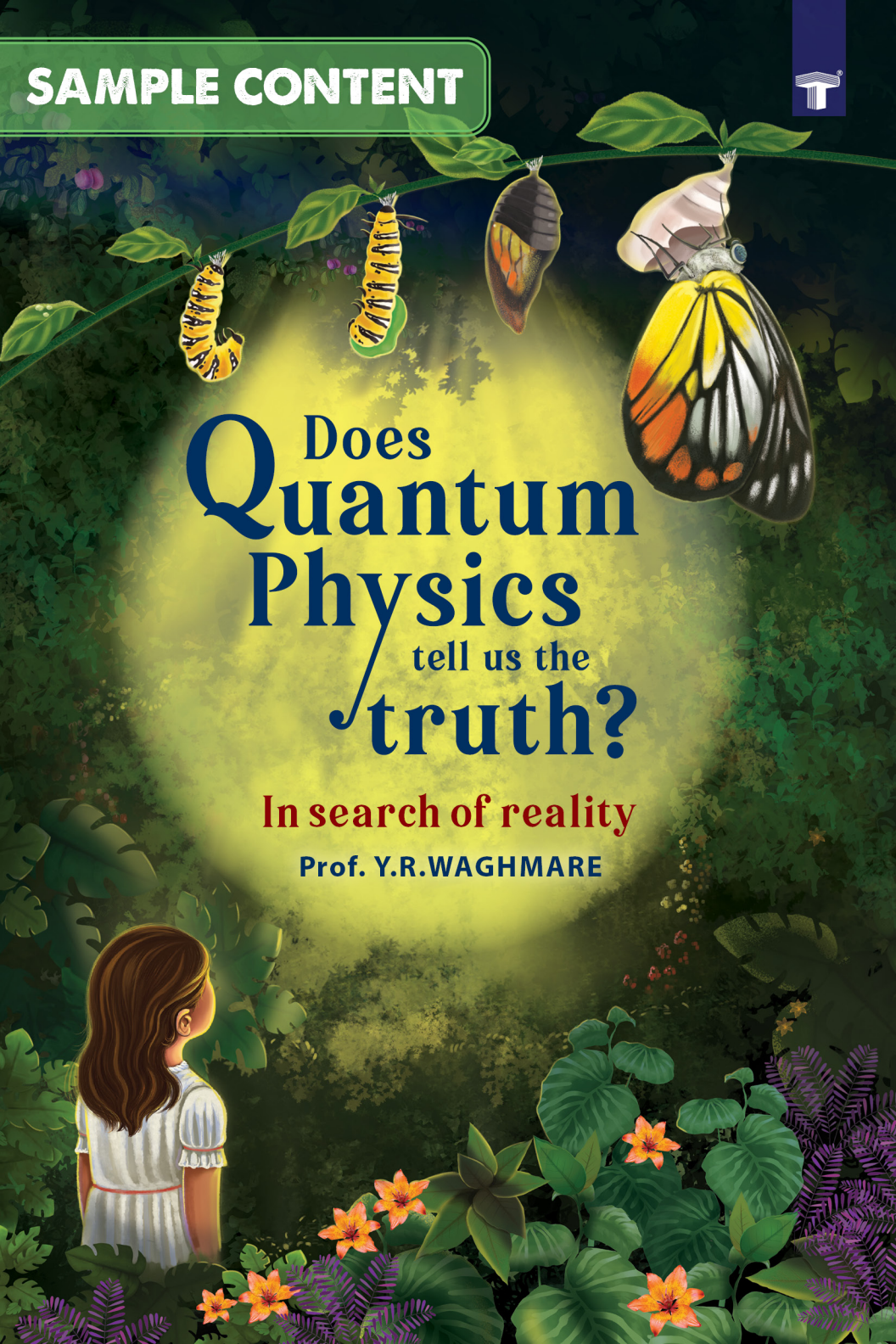

Does Quantum Physics tell us the truth?

In search of reality

Prof. Y.R.WAGHMARE

Does Quantum Physics Tell Us The Truth?

(In Search Of Reality)

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About The Author

Dr. Yeshwant R. Waghmare

Dr. Yeshwant Waghmare, former Professor and Dean at IIT Kanpur, is a theoretical Nuclear Physicist. He obtained his Ph.D. from the University of Mumbai (then, the University of Bombay), India, in 1963. He worked as an Assistant Research physicist with Nobel laureate (late) Maria Goeppert Mayer at the University of California, San Diego, and as a Research Associate at the Massachusetts Institute of Technology (MIT), USA. He has lectured in the capacity of Visiting Professor in several Research Institutions and Universities in India and Abroad (USA, Germany, France, Italy, Israel, Australia, and Switzerland). Besides shouldering other responsibilities, he is the former Vice-President of the Indian Physics Association, and also President of Indian Association of Physics Teachers.

Presently, he is serving as the Vice President of the Maharashtra Education Society, Pune. He is a Fellow of both, the Maharashtra Academy of Sciences and the National Academy of Sciences, India. He was also the Governor's (Chancellor's) Nominee on the Academic Council of Shivaji University, Kolhapur. He has published over 80 research papers in reputed International Journals, and has authored 16 books in the area of Nuclear Physics, Quantum Mechanics, Classical Mechanics, Relativity, Education, Philosophy, and other related areas.

Foreword

Dr. Anil Kakodkar

I feel privileged to be asked to write a foreword by Prof. Waghmare for his new book 'Does Quantum Physics Tell Us The Truth?'. An excellent intertwined narration of history, science and philosophy, the book brings alive an evolution of thought that has been fundamental to progress of humanity itself. The narration most certainly would be of deep interest to a wide range of common people including those interested in science, philosophy and related history.

Prof. Yeshwant Waghmare, a long-time friend, a physicist and a teacher at heart with deep interest in everything around, has really unfolded the world of science and philosophy, much like the observation experiment on *"Life cycle of a painted Lady Butterfly"*, by Uma, his granddaughter, that he has recorded in the book. The naturally flowing narration in which the key characters in history of science and philosophy come alive is truly remarkable and should make an immensely interesting read for the readers.

There are several very interesting parallels between Indian philosophical thought and modern physics that have led to many interesting dialogues between eminent physicists and philosophers. This book has captured many that the readers would find very interesting. I remember at this juncture that in 2004, our collaboration with CERN at Geneva, particularly in the context of building the Large Hadron Collider (LHC) and the experiments around it, had become very intense. We had at that time donated a 2m tall statue of Nataraja to CERN. Such an image of the dancing Lord Shiva, which as per Fritjof Capra symbolized *'a profound metaphor of the cosmic dance that unifies ancient mythology, religious art and modern physics'*, was very relevant in the context of the efforts towards the

search of understanding of our universe through a deep study of subatomic particles that was being pursued.

It is interesting that Prof. Waghmare has also linked classical music with philosophy and science through narrations around stalwarts like musical maestro Allauddin Khan, Swami Vivekananda and inventor Nikola Tesla. The book is full of such interesting narrations that readers are sure to deeply enjoy.

As a person full of positivity, curiosity and a deep interest in all that is good in life, this book seems to me to be an attempt towards a historical search of the ultimate truth in life from a variety of scientific and philosophical perspectives that perhaps would always defy a singular definitive picture in the true spirit of '*advaita*'.

We now live in a materialistic world that enjoys the fruits of science. At the same time, our view of life has probably become very self-centred leading to a lurking feeling of insecurity. Our constitution enjoins inculcation of scientific temper as our fundamental duty. At the same time, superstition seems to be on the rise. In this background, I imagine that this book would enable a more rationalized view of life.

Dr. Anil Kakodkar
Former Chairman,
Atomic Energy Commission, India

Preface

It is customary to firmly believe what one sees or experiences. If one plucks an apple from a tree, one surely knows that it is no longer there. If one pushes a table it will move. By observing the moon, one realizes that it moves in the sky. So do stars and planets. If one throws a ball vertically upwards, then, depending upon the force with which one throws it, it will reach a maximum height and return to the ground under gravity. This phenomenon follows Newton's law of gravitation. If the ball is thrown vertically up with a speed of 11.2 kilometres per second (km/s) it will never return to the earth. This velocity is sometimes called the *escape velocity* (with respect to the earth). On the other hand, if an attempt is made to throw a ball or an object, from a 'platform' which has an infinitely large mass/weight, it will not leave the 'platform'. Such a 'platform' is referred to as a '*black hole*'.

Nothing escapes from a black hole, not even light. Newton's physics tells us all this. Newtonian physics is based upon observations and experiences, initially observed by Newton, and subsequently confirmed by others.

There are several manifestations of Newtonian physics. For example, the law of gravitation explains where the sun and the moon will appear on the horizon every day and night. In fact, a major characteristic of Newtonian physics is that it is *predictive*. For example, if all initial conditions and forces acting on an object are known, one can predict the state of the object at any time in the future. Hence, Newtonian physics is also called *deterministic* physics.

Einstein was highly impressed by Newtonian physics, which he termed as *classical physics*. His only departure from Newtonian physics was in the *definition of the coordinate system*. Newton's coordinate system contained 3+1 variables, three space coordinates, and one independent time coordinate. For Einstein, all these four coordinates were dependent upon each other. In other words, the Newtonian world was three-plus-one dimensional, while Einstein's world was four dimensional. The difference between the world coordinates created the contrariety in Newtonian physics and Einstein's theory of relativity.

However both theories agreed on two counts, which Einstein summarized in terms of two principles: *(i) the principle of independence* and *(ii) the principle of realism*. All classical objects are physically realizable, and

therefore, they form a class of *classical reality*. When a magnet is brought near an iron piece, it attracts the piece towards itself. However, once separated, the iron piece and magnet go back to behaving independently as if the interaction had never occurred. Quantum theory of Niels Bohr and Heisenberg differs from classical theory of Newton and Einstein in both these aspects.

Quantum theory, originally proposed by Max Planck and subsequently developed by Heisenberg, Dirac and others, differs fundamentally from the classical theory; it rejects the two Einstein principles. Firstly, according to quantum theory, two objects if they have interacted once, will keep on interacting forever, even if separated in time and space. Secondly, according to quantum theory, *reality is observer-created*. On both these counts, Einstein and Bohr differed violently. According to the assertions of quantum theory, as emphasized by Bohr, the moon is *not a reality for anybody who is not looking at it*. According to Einstein, even if one does not look at the moon (even during a full moon night), one knows it exists. Similarly, according to Einstein if two objects interact strongly, they will behave *independently* when separated. But, as mentioned earlier, according to Bohr they will still interact with each other even if they are '*separated in space and time*'. Quantum theory flouts the principles of classical physics, but its *results are physically realizable*.

Thomas Young's double-slit experiment (1801), discussed in chapter 1 (and also in chapter 2), opposed Newton's corpuscular theory of light and supported Huygens's wave theory (both were contemporary theories from the 17th century). The corpuscular theory reigned almost for 150 years, along with Huygens' wave theory of light. However, this theory could not successfully explain the observed phenomena of diffraction and interference. Therefore, it was abandoned. On the other hand, Young's observations supported the 'quantum' hypothesis of Max Planck (1901), which considers light (an electromagnetic wave) as a wave as well as a stream of particles. In other words, the particle of light, which was subsequently called the *photon*, has a *dual nature*. It behaves as a particle as well as a wave.

During the twentieth century, classical physics reigned supreme. However, further studies on electromagnetic radiations exposed its limitations, and, therefore, it had to be replaced by quantum theory. It was now the turn of this new theory to develop new technologies, in various forms, which we are still using today. Until the end of the nineteenth

century, classical physics was widely accepted and no one noticed any *internal contradictions* in it. It almost seemed as though research in physics *had come to an end.*

Oscar Wilde, the famous British novelist and writer of plays, said, "Nothing succeeds like success". Einstein contradicts this statement when he states that; *"Momentary success carries more power of conviction for most people than reflections on principles*". He further added, "Quantum Mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the 'old one' (classical science). I, at any rate am convinced that *HE* (God) is not playing dice".

With the success of quantum theory, came the scrutiny, and the question of reality once again surfaced. The *uncertainty principle* of quantum theory posed a serious philosophical problem. The necessity of an *external observer* during the process of measurement challenged the role of *mind-matter interaction.* The role of *consciousness of the observer* and its relationship with *physical reality* was now imperative. Scientists began looking for answers to the questions, such as "What *is* consciousness? Does it have a physical reality? Where in the brain does it reside, if at all? How does the brain connect the consciousness with the *mind*, and is the mind *different* from the consciousness?" Swami Vivekananda stated, *"Consciousness creates illusion (maya) and illusion creates material world."* If that is so, *'is the world a reality or an illusion*?'

Several scientists have made a variety of suggestions ranging from pure philosophy to biology to mathematical formulations, such as by Tononi. Roger Penrose, in his book *'The Emperor's New Mind*', suggests that *'consciousness is created by some mysterious quantum mechanical phenomenon that takes place in brain cells'*. He points to a component of the brain cells that appears to be in an ideal location for quantum mechanical phenomena. The component, is known as a *microtubule*, and believed to be the *physical root of consciousness.* Penrose wondered if a computer could be programmed to acquire something that parallels human consciousness. Similar suggestions are made by other scientists such as Stephen Hawking.

We recall that in 1913, Niels Bohr, to explain the occurrence of the electromagnetic spectrum of the hydrogen atom, proposed that electrons in atoms move in *stationary* circular orbits. That is, the electrons do not emit energy (radiation) while orbiting around the nucleus. This was a fantastic proposition, and in contradiction with the idea of classical physics. The

experimental results of spectra of all the atoms were observed to be consistent with this notion.

It is believed (as mentioned in the *Vedas*) that *soul* and *atman* are two sides of the same *coin*, and they coexist. It is like the dual nature of matter; all matter exhibits particle as well as wave aspects, but only one at any particular moment, and never together. *Consciousness plays the role of the 'coin'*. In any case, the sides of *this* coin cannot be viewed simultaneously. The search for an explanation for reality will continue, until scientists can photograph an *electron in a stationary orbit*, thus violating the present version of quantum theory. *This is the site where the consciousness resides*!

Yeshwant R. Waghmare
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Introduction to the Author

- Dr. Ruta Waghmare

It is an honour and a pleasure to write an introduction for Dr. Yeshwant Waghmare's alias baba's book. No, he did not ask me to write this. I want to write this because I want to share with the readers a few things about baba that he would not share with you on his own. It's truly my pleasure.

I've known baba all my life- literally. I could go on and on about what an incredible person and father he is, but honestly, he's a rare gem!! I've never, NEVER met anyone as well-rounded (and excelling in all dimensions) as him. He's an incredible artist! When people visit my house (which displays several pieces of his art work), they are stunned when they find out that some of the art work is actually by baba. In his younger days, he was an amazing athlete. He was not only the captain and opening batsman of the IIT Kanpur faculty cricket team, but also represented the faculty team for badminton and table tennis. And although singing is just a hobby for him, he can actually carry a tune pretty well.

His academic and professional record is stellar. He got his Ph.D. with Dr. Sudhir Pandya at PRL Ahmedabad, and his postdoctoral work was at the University of California, San Diego, with Dr. Maria Meyer. During his time as a postdoc, Dr. Meyer got the Nobel Prize, and baba was one of the closest people to witness the entire process! After his postdoc, he went to MIT as a researcher for 2 years, and proudly returned to India as an Assistant Professor at IIT Kanpur. He was the only faculty member at the time to have been hired with full-tenure. He has written 17 books, ranging from physics to more metaphysical topics.

Baba's academic record is unparalleled, but more importantly, he's genuine at heart, and the kindest soul. If I was to count the number of students or number of times students came to our house while I was growing up, it would easily be in the thousands. We always had students stay back for lunch, dinner, snacks and of course, baba's advice. Baba continued his passion of mentoring students even after retirement where he mentored many in Pune, and they have been very grateful to him for his guidance.

Baba has always been fascinated by physics, but his interests extend way beyond it. The prime question- "does our consciousness create our reality?" has been on his mind for many years, and he has devoted the last decade on research and writing books on this topic. This book is another one of his masterpieces that makes you think, and wonder about the nature of consciousness, duality and non-duality, and provides clarity on many of the fundamental questions we, as human beings and souls, have been exploring for centuries.

I hope you enjoy this book as much as I have.

About Dr. Ruta Waghmare

Ruta Waghmare is Vice President- Scientific Affairs and Laboratory Services at Pall Biotech, USA, and leads a team of ~300 scientific experts that provide technical support and services to customers. She is passionate about using science and engineering to enable the development of life-enhancing drugs.

Prior to joining Pall in September 2018, she held several positions at MilliporeSigma/Merck Millipore. Starting from the year 2000, her various roles included Senior Director – Marketing Communications and Shared services, Senior Director – Market Sales Development, Director – Emerging Biotechnology, Regional Sales Manager, Head – Chromatography (Americas), and Group Manager – Process Development Sciences. Ruta has co-authored over 65 publications and conference presentations, majorly with her customers. She also served as an officer (including Chair) for Manufacturing Sciences and Engineering section for AAPS (American Association of Pharmaceutical Scientists) from 2012-17.

Prior to joining MilliporeSigma, Ruta did her postdoctoral research at the NIH (National Institutes of Health, Bethesda, Maryland) on protein purification and crystallization.

Ruta holds a B. Tech. in Chemical Engineering from IIT Kanpur, India, and a Ph.D. in Chemical Engineering from Iowa State University.

Contents

CHAPTER 1

THE MAGNIFICENT ISAAC NEWTON!

Nature is beautiful. Life is beautiful. To understand nature, one life is not enough. Natural science is not yet fully developed. The famous nuclear scientist and philosopher, von Weizsäcker once said, "*Nature is earlier than man, but man is earlier than natural science*". Man developed natural science for understanding nature and natural phenomena. He first thought that God is the creator of all nature and therefore his only role was to appreciate it. Soon he realized that for his own survival, manipulation was necessary. He created fire by rubbing two polished stones together. He learnt the art of creating utensils, weapons, and other artefacts. Soon his creativity flourished. He learnt to manipulate nature. The expanse of his artistic knowledge increased. He started categorizing nature and developed skills to understand nature's intricacies. He started enunciating laws derived from experiences. Everything that he observed must be understood in terms of the laws that he formulated. If some observations did not satisfy established laws he modified the laws or just ignored them as 'God-given'.

The history of the development of science from times immemorial is not the object of our present book. On the other hand, it concerns understanding how *philosophy* got entangled with *science*. How philosophy turned into science, and vice versa. This entanglement exists even today. All the major breakthroughs in science and technology took place under the umbrella of philosophical thought. As time progressed and human

intellect developed sophisticated tools for exploring nature, further categorization and branching took place. This branching did not stop at the splitting of science into physics, chemistry, biology, etc. even though they shared the same underlying philosophy of governing nature through *interactions* of ingredients of specimens. Eventually, even the size and state of the specimen (solid, liquid or gas) became a thing of contention. Language changed and so did science and its laws.

There was a period, around the nineteenth century, when some leading scientists thought that all that was necessary to be known for understanding nature was discovered and there was neither further scope nor necessity for research. However, this prophecy was soon proved false. By the turn of the twentieth century, science had flourished and continues its unrelenting march to this day. It is now believed to be unstoppable because of newer developments taking place. Modern science (with quantum mechanics and the theory of relativity) has taken over from where classical science left off in the twentieth century. This was the stage when the science of macroscopic objects (which can be seen by the naked eye) and the science of microscopic objects (unseen by the naked eye or even through microscopes, but whose existence may be inferred indirectly) such as elementary particles like electrons, neutrons, protons etc., got separated.

Though modern science flourished in all its splendour in the twentieth century, its seeds were sowed as early as the seventeenth century. Its origin may be traced to a village fair held near Isaac Newton's village. Young Isaac's mother Hannah learnt about this fair and in order to expose Isaac to interesting experimental magic exhibited by the professionals, decided to take him to the fair. Isaac was truly excited to see the offerings at various stalls ranging from mouth-watering foods, interesting games, loud speeches (of really no relevance), animal shows, eye-catching gymnastics to 'magic of science'. It was actually an annual event and it was Hannah's desire to educate her son in a variety of ways. She took utmost care of her first child who was unlucky to be born just three months after the death of his father. His father was a prosperous farmer and as was common at that time, he shared his name with his son. Being born prematurely, but with all the blessings on Christmas Day, 25th December, 1642, Newton was just a small child. He was born in the same year that Galileo died. Was Isaac Newton a reincarnation of Galileo?

Isaac's mother, Hannah Ayscough, used to say jokingly that 'he could fit inside a quart mug'. Isaac had exhibited brilliance right from his childhood and his mother and other relatives were very proud of him. When Isaac was three, Hannah remarried and went to live with her new husband, the Reverend Barnabas Smith, leaving her son in the care of his maternal grandmother, Margery Ayscough. This alliance was brought about by the church clergy after three years of waiting by Hannah. Hannah had three children from Barnabas Smith. Young Isaac disliked his stepfather and maintained a distant relationship towards his mother due to this remarriage. It was in his grandmother's care that Newton's talents flourished. However, it was indeed kind of Reverend Barnabas to leave a large estate in Isaac's name. It is pointed out by historians that Newton did not have any lineage of brilliance from either of his parents or their predecessors. However, his mother certainly had the requisite qualities and brilliance. Newton was taken care of by Mrs. Catherine Barton Conduitt (his sister's daughter) and family. It is said that the story of the '*falling apple and the law of gravitation*' was fabricated by Catherine who told it to the then famous French novelist Voltaire (real name François-Marie Arouet). The story runs thus:

Once, Isaac Newton was sitting under an apple tree. He was thinking about why the Earth and so many stars revolved around the Sun. He was very fascinated by these shining celestial objects and was wondering about the secrets of the Universe, when suddenly, an apple fell on his head. For a moment he was shocked or taken aback, and then puzzled. If it were any other normal person in his place, in all probability, he would have just taken the apple, examined if it was sweet or sour, and just eaten it, without worrying why it had to fall on his head just because he was sitting right under it. Newton was not a normal person; he was rather extraordinary. This event shifted his brain into gear, which finally resulted in Newton proposing his famous 'Law of Gravitation'. Newton's concentration while working was so intense that it used to '*burn the darkness of ignorance*', just as the sun's rays burnt a piece of paper when focused on it. It is well-known that the mind is the greatest entertainment theatre ever created, and it is the 'inner mind' that disturbs one's concentration, if not controlled.

There is an exemplary story about the concentration of the mind. It concerns the famous scientist Archimedes. It is said that when the Romans

defeated the Sicilians, Archimedes, who was the royal mathematician as well as the defence minister of Sicily was engrossed in solving a problem concerning geometry at his residence. Some soldiers, who had neither any knowledge of mathematics nor had ever heard the name of Archimedes entered his house and attacked him. When they were about to slaughter him, he shouted, "*Just wait for a few seconds. I have found the solution*". Obviously, Archimedes had no knowledge of what was going on around him. It is said that the Roman King Marcellus held Archimedes in high regard. So when he heard about the tragic end of his most respected scientist he ordered the assailant to be captured and hanged publicly. He also came to know of Archimedes' 'last wish' which was that his tomb should have an inscription of a geometrical figure depicting a cylinder and a sphere contained in it, and their relationship in terms of their volumes. The king erected such a monument in Archimedes' honour.

As mentioned earlier, the story of Newton and his law of gravitation vis-à-vis the falling apple, was concocted by Newton's niece, Catherine Barton Conduitt, who used to keep Newton's friends and visitors occupied by telling such stories about her uncle along with some other interesting episodes, until Newton had time to meet them. One such visitor was the famous French novelist Voltaire who was also charmed by Catherine's beauty. He writes about her:

"

At Barton's feet the God of Love
His Arrows and his Quiver lays,
Forgets he has a Throne above,
And with this lovely Creature stays.
Not Venus' Beauties are more bright,
But each appear so like the other,
That Cupid has mistook the Right,
And takes the Nymph to be his Mother.

Fig. 1.1 Catherine Barton

"

Catherine's fame, or may be her notoriety, extended beyond London to the continent. Rémond de Monmort, a member of the French Regency

Council, who met her in 1716 whilst visiting Newton, later wrote of her, *"I have retained the most magnificent idea in the world of her wit and her beauty"*. More famously, Voltaire wrote of her:

"I thought in my youth that Newton made his fortune by his merit. I supposed that the Court and the city of London named him Master of the Mint by acclamation. No such thing. Isaac Newton had a very charming niece, Madame Conduitt, who made a conquest of the minister Halifax. Fluxions and gravitation would have been of no use without a pretty niece".

This is going a little too far. Catherine's beauty and Newton's law of gravitation were mutually exclusive! Incidentally, Catherine's husband, John Conduitt, was equally famous as a brilliant scholar and had secured all the honours that Newton received, including Director of the Mint. Because of his duties as Member of British Parliament and Ambassador to various countries, it suited the Conduitts to have a permanent residence with Isaac Newton.

It is not our intention to sketch a complete biography of Isaac Newton. What we are going to elucidate is the impact that his excursion to the village fair had on science. Indeed, Isaac was greatly enjoying the ambience and his mother saw to it that he took a keen interest in the so-called 'magic of science' shows. One of the shows particularly attracted Newton's attention. There was a white paper and there were very beautiful 'colour bands' on it. Newton became curious to see that experiment. He left his mother behind and ran towards that experiment. Hannah did not understand why her inquisitive son ran so fast towards that particular experiment. She had seen this magic on earlier occasions. 'It is just natural', she had thought. However, what that 'natural' was she did not know. It was left to her son to find it out.

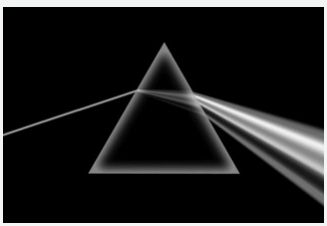

Fig. 1.2 Decomposition of white light into the colours of the spectrum by prism

Newton went close to that experiment and observed its profound beauty. He first saw that there was a glass piece of a particular shape that was hanging some distance away from the paper. He asked what that glass piece was. He was told that it was called 'prism'. Besides Newton there were many other young 'scientists in the making'. They all wanted to understand the experiment; particularly, where the colours came from. In the ensuing tussle, the glass piece, namely the prism, was disturbed and the colours vanished. Every one blamed the other for this. Some even left the experiment and went elsewhere to find something else to amuse them. However, some remained; they wanted to see if the colours could be regained. Everyone tried, but with almost no success. But Newton challenged his brain and figured out the possible reason. He got the answer. He readjusted the positions of the prism and the paper. And lo! There was the spectrum of colours once again. Everyone was surprised. Isaac repeated this experiment several times at the stall as well as at home. He now understood the reason for the 'dispersion' of colours when white (sun) light passed through the glass prism. He also repeated this experiment with glass objects of various designs. However, the most beautiful spectrum of colours was obtained when sunlight was passed through the glass prism (see Figure 1.2). He also measured the 'deviation' of each colour from the direction of the incident sunlight. The spectrum consisted of seven colours: violet (V), indigo (I), blue (B), green (G), yellow (Y), orange (O), and red (R). In short, the sequence of colours was VIBGYOR.

He suddenly recalled having seen these colours in the sky in the form of a *rainbow*. The colours in the rainbow ranged from violet to red in the sequence of violet, indigo, blue, green, yellow, orange and red (from outer to inner side in that order) and also followed the VIBGYOR seven colour sequence). This spectrum of colours fascinated him. Suddenly a thought came to his inquisitive mind: 'How and why does the sunlight, which looks predominantly white, get decomposed into a spectrum of colours?' He soon realized that the sunlight must intrinsically consist of all these colours, but when they get mixed they look white. It must be the property of the prism to separate them again. But what happens in a rainbow?

Newton soon came to the conclusion that the water molecules in the atmosphere must be responsible for it. He also realized that a rainbow is a section of the cone formed when sunlight is scattered at an angle of about 42 degrees (with some dispersion in the angles of violet to red colours)

with the sun-observer axis. He demonstrated the wave nature of light and the 'phenomenon of interference' through what we now call 'Newton's rings'. This idea was not new. His adversary, Christiaan Huygens, had already proposed it. What bothered Newton was the 'heat' associated with (sun) light.

Newton had experienced that if he stood in sunlight for a good length of time, the 'heat' became unbearable. He realized that there was a transfer of energy from sunlight to his body. He also knew that such a transfer would take place only if the 'colours' actually consisted of a 'stream of particles'. He called these particles 'corpuscles'. It was also his (logical) conjecture that the corpuscle of light of each colour would also have the same colour as the colour of the light itself.

Incidentally, in the room in which Newton was born, there is a drawing of an apple tree on the wall, and over the fire place is a stone tablet inscribed with Alexander Pope's couplet "Nature and nature's Laws lay hidden in night, God said *"Let Newton be! And all was Light!"*

In order to explore the stars and planets, Newton had devised a reflecting telescope for which he was awarded the title of '*Fellow of the Royal Society (FRS)*'.

His next set of experiments consisted of light passing through lenses. In one particular experiment, he kept a flat glass plate with a convex lens on top of it and directed light of just one colour (so called 'monochromatic' light) on the lens. When he observed the reflected light, by means of a microscope (which he himself had fabricated), he found beautiful *concentric rings*, of the same colour. This was indeed an 'interference' pattern. Newton continued his experiments with light of various colours and that opened a new discipline which came to be known as '*Opticks*'. Thus, the origin of 'opticks' may actually be attributed to Newton's visit to the village fair. Newton's *corpuscular description* of light was a *plausible* description of light and it was accepted by the scientific community as such. However, as mentioned earlier, that was not the only description of light known then. The other description of light was that 'light consists of waves'. This was proposed by Christiaan Huygens. Both these approaches were successful in explaining most of the observations on a variety of experiments done with light in those days.

Though Huygens and Newton appreciated each other's works, Robert Hooke (of the famous Hooke's Law of elasticity), Curator of Experiments at the Royal Society of London, was highly jealous of Newton. At every stage, whenever he got an opportunity, he used to criticize Newton's science, physics as well as mathematics. His usual target was Newton's famous book *'Principia Mathematica'*. As Hooke was occupying a 'power seat' Newton could not do much about it. However, when he became the President of the Royal Society, after Hooke's death, the first thing he did was to remove Hooke's portrait from the Gallery of the Royal Society. This was the revenge Newton took of Hooke. Incidentally, Robert Hooke, like Newton, never married and stayed with his niece, Grace Hooke, all his life.

Newton left *'Opticks'* at that time! He did not worry about 'why the sky was blue'. This phenomenon was explained by Lord Rayleigh on the basis of the (classical) wave theory of light, and later by Sir C. V. Raman on the basis of Quantum Theory. It is worthwhile to mention what Einstein thought of 'light'. Einstein had said, *"All these fifty years I have been working hard to understand what this object* ***photon*** *is, but I am nowhere near its understanding. These days every Tom, Dick and Harry thinks that he knows it. But he is mistaken"*. Incidentally, photon is also a quantum of light, but it has totally different characteristics from Newton's coloured corpuscle.

Scientists knew that both the descriptions, Newton's as well as Huygens', were so contrary to each other that they could not be right simultaneously. However, they could not think of any experiments which would resolve this dilemma. The result was that both these descriptions were accepted as such for almost 150 years. It must have been a great challenge for the science teachers at school to convince the students of this dilemma. This paradox of whether light could be treated solely as a stream of particles or as waves, i.e., Newton versus Huygens, was finally resolved by the ingenious experiment of Thomas Young in 1801. The original experiment that Young performed was intended to measure the velocity of light, and it used everyday items such as cardboard pieces, mirrors and sunlight. Our purpose of discussion is to understand the result that Young obtained. Therefore, we shall describe its sophisticated version which one uses in our undergraduate laboratory. The main part of the apparatus will include a laser gun (to provide a monochromatic source of light), two identical parallel slits carved on an opaque plate, and a screen on which we

Anil Kakodkar: "An excellent intertwined narration of history, science and philosophy, the book brings alive an evolution of thought that has been fundamental to progress of humanity itself. The narration most certainly would be of deep interest to a wide range of common people including those interested in science, philosophy and related history".

Voltaire's remark on Newton's popularity: "I thought in my youth that Newton made his fortune by his merit. I supposed that the Court and the city of London named him Master of the Mint by acclamation. No such thing. Isaac Newton had a very charming niece, Madame Catherine Conduitt, and gravitation would have been of no use without a pretty niece".

Dalai Lama, in his conversation with father Desmond Tutu (both Nobel laureates) had said, "Sometimes I do meditation of self using what is known as the sevenfold analysis…For example, now when I look at you, and I analyze, I see that this is my dear, respected friend Bishop Tutu. No, this is his body, not himself. This is his mind, but not himself… In quantum physics, they also have a similar view. Any objective thing does not really exist. There is nothing ultimately we can find. This is similar to analytical meditation".

Swami Vivekananda: "With all its inhabitants, universe is 'maya'. Maya means illusion". According to Swamiji "the goal of reality is experience, 'freedom from oneself'. The distinction between self-realization and physical matter, between mind and body, is the result of this freedom. The dual nature of matter, matter as having both particle and wave aspects, therefore, corroborates dvaita philosophy".

Albert Einstein's argument with Niels Bohr (on the definition of reality): According to Einstein, "The Moon is real, even if we do not look at it". Bohr responded with, "The Moon is not real for you if you are not looking at it". This is the essential difference between classical and quantum theory.

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