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The Eyries and Pyres of Thought

High Schooler's Guide to Philosophy and Science

TEDEd Clubs

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The Eyries and Pyres of Thought

An R. N. Podar School--TED-Ed Club's presentation

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Preface to the Volume

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science." -- Albert Einstein

"The irony of the life is that it is lived forward but understood backward" -- Soren Kierkegaard.

The genesis of all that we know to exist is an event that will likely forever remain mystical in nature to the likes of us. For so many aeons have we ploughed on, wishing for answers, reaching out within us and beyond us to discover the hidden secrets of the cosmos, driven on by something in us, something that transcends articulation. It is an endless journey, and our destination is but a chimera, but we care not.

When did this journey begin? Humanity has been forever pulled towards contemplation and thought by some unquantified force. Every event to ever have occurred has lead up to this unique point in the infinite vastness of space-time, but when did the Universe open its eyes in such cosmic majesty and begin to question itself?

Questions stemming from knowledge stemming from thought stemming from consciousness, but where are the answers? Knowledge, thought, consciousness...what are these things that have so far left the physical sciences groping around desperately in the dark? We are seafarers in the midst of an endless ocean, struggling to stay afloat in our search for the truth-without even knowing if such a thing exists. We set sail a long, long time ago, and land was never in sight-but we are not deterred.

For we wish to know.

Perhaps two and two can make five. Perhaps nothing really exists apart from you; perhaps the cosmos is a product of your fevered imagination and you are all there is. Is mathematics a human invention and just as flawed as any other or is it the bedrock on which the Universe is propped up? How may we ever distinguish between that which exists and that which is an illusion projected by a biased cognitive system?

What is to know something? How does your brain interpret everything it perceives? Such questions plague scientists even today. Questions like these often appear when one tries to study fundamental concepts and phenomenon. Few of the most puzzling questions today are regarding the human brain itself. What makes us conscious beings, organisms that are self-aware on many different levels? What makes up our mind? How is it different from a brain?

An excerpt rightly sums the mysteries revolving around the brain :

"How can a three-pound mass of jelly that you can hold in your palm imagine angels, contemplate the meaning of infinity, and even question its own place in the cosmos? Especially awe inspiring is the fact that any single brain, including yours, is made up of atoms that were forged in the hearts of countless, far-flung stars billions of years ago. These particles drifted for eons and light-years until gravity and change brought them together here, now. These atoms now form a conglomerate- your brain- that can not only ponder the very stars that gave it birth but can also think about its own ability to think and wonder about its own ability to wonder. With the arrival of humans, it has been said, the universe has suddenly become conscious of itself. This, truly, it the greatest mystery of all." ~V.S. Ramachandran [The Tell Tale Brain: A Neuroscientist's Quest for What Makes Us Human]

The human brain has been shaped through many generations of evolution. Evolution has hardwired our brain in many different ways to aid us in survival. For instance, try shaking your head. You see the world stay where it is. But now take a camera and record a video while shaking the camera. The surroundings shake violently along with the jerks of the camera. Although we move our heads and use cameras on daily basis, this subtle difference is not usually noted. The brain is continuously reforming images and clearly our vision compared to the video on the camera provides a survival bonus. Our brain is a marvelous by-product of evolution which can and does contemplate everything from society to people, from Newtonian events to Quantum physics, from the universe to itself.

But is the scrutinization of quantum phenomena really possible by this three pound jelly-like substance sitting in our heads? Are we really capable of understanding the entire of macrocosm in terms of the quivering and bobbling of atoms?

Since our birth we've been experiencing events in this classical world. The world to us seems so predictable. You don't anticipate a car moving in the lane parallel to yours to just vanish and reappear in some other lane. Does it ever strike you that a football can pass through the body of a player without altering its internal structure and reach another player across the field? Even the thought of such an event seems so ludicrous that any prospect of it happening in the real world appears to be out of question. After all, it is the occurrences of this real world of ours that we keep as a measure of plausibility of other events. But is our real world really that credible for it to be kept as a standard measure ?

The introduction of the quantum theory perturbed the greatest of scientists of the era in which it was founded, since it challenged the most rudimentary processes of thinking. It was this bafflement which led David Deutsch to quote- *So counter-intuitive are quantum theory's predictions that, under the leadership of one of its pioneers, Neils Bohr, a myth grew that there is no underlying reality that explains them*.

The laws that underpin quantum mechanics are based on probability. Nothing can be stated to happen or be for sure, be it a particle's position, velocity or any other attribute. This is the sole reason why quantum mechanics when juxtaposed with the classical world (or the world that we perceive) is so starkly different. We are composed of these tiny particles and so are the objects that we are able to discern. So why is it that the weird phenomena that govern these quantum bodies cease to exist when magnified to the objects in the classical worlds? Can the question of life be answered in terms of the movement nanoscopic particles which behave in an arbitrary fashion?

"*God doesn't play dice with the universe*", to quote Einstein. Or does He?

Jumping from the spooky world of quantum mechanics to the more logical and intuitive world of relativity, it's really surprising how a change in scale can bring such a quantum leap in the underlying properties governing these systems.

At the quantum level, the notion of space turns out to be discrete, electrons can pass from one point to another without passing through the region in between. The notion of time is fuzzy too. There are experiments at the quantum level which question the fundamentals of time itself. Do the electrons actually time travel at the or time flows in a different way in the quantum realm?

Which notion of time is the correct one? We can choose to fix the classical notion and call the quantum notion wrong and vice versa. But which notion is the supreme truth of our cosmos? The answer is that we don't know.

General Theory of Relativity is commonly associated with phrase "Geometrization of Physics". The geometry of the universe is produced by gravitational fields. Hence the theory does not reduce gravitation to geometry, it is the opposite, geometry is based on gravitation.

But do we know which is "our" universe? The Einstein Field Equations for more than hundreds of years have been elegantly predicting any new observation of the universe. There are many solutions to these equations, some of them exact solutions, which satisfy the field equations completely and some of them not exact, which are just approximations.

The problem arises out of the cosmological predictions of these solutions. There are exact solutions to the equations which predict a universe where time traveling is not a thing of the fairy tales but a reality, where a solution that predicts the Star-Trek fantasy of "warp drive", that objects would traverse distances by contracting space in front of it and expanding space behind it, resulting in an effective faster-than-light travel, where solutions predict (and we have observed to be true) black-holes, which is the meeting point of quantum mechanics and relativity, where all the laws of physics break down and whose existence has bothered physicists for decades.

But which of this is the solution which truly satisfies the situation of our universe? As we go on discovering new corners of the cosmos, the solution we think is the most correct might change but the one true solution still remains unknown. Our notion of this macroscopic universe is build up of two fundamental quantity, space and time united into a mesh of continuum called space-time.

Since ages, philosophers and scientists have deeply thought about the nature of time. It was said to be absolute, the one quantity that is said to flow independent of our existence but in this relativistic universe, time is subjective. It depends on how fast you are traveling. It is not only subjective, it is also completely emitted from the picture. There is no concept of time, there is no simultaneity. Things happen in space-time, not time.

Same goes with our notion of space, another quantity that was thought to be human independent.

So the questions still remain…

What is space? What is time? What is the true nature of the universe? We don't know the answers to these questions yet. We could say that time will tell the answers, but it doesn't exist in a relativistic world...

In our series of newsletters, we will be expositing on things that have boggled mankind for centuries, and man's spectacular ignorance throughout his life will be starkly exposed, along with how lightly he takes things like time and his ability to question the cosmos, and the very existence and nature of the cosmos itself.

Mankind's greatest tool in achieving all its intellectual feats has been the sheer emotion of curiosity. Our advice to the reader is same:

Quaerendo Invenietis.

Aditya Dwarkesh
Ameya Kunder
Kiranbaskar Velmurugan
Pulkit Malhotra

Editors' Note:

We would like to make it extremely clear that no prior expertise in any of the fields is required on the reader's side to follow the course which will follow. The contents and the text that flies within the newsletter is tailored to perfection and is original.

Contact us at mail.teapot@gmail.com

(TEAPOT-- The Eyries And Pyres of Thought)

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Philosophy — The Essentials

By Aditya Dwarkesh

"What is your aim in philosophy?
To show the fly the way out of the fly-bottle."
-Ludwig Wittgenstein

The world 'Philosophy' is one with rather grandiose connotations in even its most everyday sense. Its utterance conjures vivid images of lordly men conversing beside a quite fireplace on deeply important matters with profound implications to some, of socially outcast shut-ins with horrible hairstyles buried underneath tons of books and paperwork to some-and, admittedly, to some, a bunch of old idiots with nothing better to do than to argue into the air about some vague and ridiculous notions that don't matter anyway.

So what is philosophy? Is it just an elegant-sounding word referring to droll and useless debates? What is it that gives the word that aura of intellectual bliss? Why did the chicken cross the road?

I digress.

Philosophy is, in a very important sense, thought itself: to think is to philosophize. Philosophy is a direct and unavoidable consequence of the ability to think coherently (in the usual sense of the phrase). The very cogs of the Universe have been configured in this inviolable manner. I am, however, making a distinction between life and thought! Blue-green algae, although undeniably alive, are not philosophers-they lack the ability to think as we do. If the thought is sufficiently sophisticated, philosophy will arise.

Does this mean apes are philosophers? Yes indeed-apes would have, in an equally important sense, been the very first philosophers (but don't go around telling people that you fed a group of philosophers bananas unless you want to be thrown and locked in a rubber room).

Philosophy has often been called the mother of sciences, and while that is a mighty title to carry, philosophy does it with ease. The word itself is derived from the Greek words 'philos' and 'sophia', and their conjunction literally means "the love of knowledge." Philosophy is an enquiry into everything: if something can be questioned, it will be questioned. It has no limits, no boundaries. It seeks the answers to everything there is. This is a road that may neither end nor lead us anywhere and all we can do is keep questioning everything blindly, but-to quote a short, beautiful and very famous poem-: Not all those who wander are lost.

Philosophy can be broadly split into four categories: Ethics, aesthetics, metaphysics and logic or epistemology. Metaphysics is concerned with the search for what there is. This makes all the natural sciences its descendants; they are observation and experiment-based attempts to deduce and uncover that which exists objectively and its nature.

The popular belief is that metaphysics is a wooly and airy branch of thought. While I do concede that it has a tendency to jump around abstractions, the eventuality metaphysics wishes for is to have the scales torn away from our eyes and the truth and its nature exposed. Metaphysics is the search for what exists objectively and fundamentally in our cosmos.

Logic and epistemology refer to the art of correct thinking and the study of human knowledge, respectively. It is logic which comes to our rescue when statements such as "The Earth is flat" are made. (The probable chains of thought that lead to this conclusion are about as far from being correct as the Earth is from being flat.) Logic questions the way we draw inferences and epistemology questions the methods used for procuring knowledge. Together, they attempt to ensure that we make no misstep in our search for the truth.

Ethics and aesthetics, now… these are words in common parlance, but ethics and aesthetics lie on a different plane altogether.

Ethics is the study of what is good and what is bad and other such values; aesthetics deals with beauty in art, literature, and other related attributes. Why do I say they lie on a different plane altogether?

Ethics and aesthetics are based entirely on feelings. Curiosity, beauty, love, good, bad-all words which refer to such delicately and completely subjective things. How may we ever strip our biases to fix an objective meaning for them when their very meaning is so purely subjective? As far as we are concerned, ethics and aesthetics are simply unquantifiable: we cannot analyze these in the same way we may analyze an atom or a mathematical theorem. A real pity, for knowledge can take us far, but we'd trade it all for just a little peace of mind.

My tabulation of philosophy shall cease here, for as the thinker Will Durant put it when he himself did so: "These are the parts of philosophy; but so dismembered it loses its beauty and its joy."

Perhaps the manner in which I equated philosophy and thought previously now becomes clearer. How can an organism which thinks in the sophisticated manner we do not philosophize? It will think about what to make for dinner, it will think of how to cook what it wants to make, it will think about why the fire it will use feels so hot, and there you have it! It would have stepped into the realm of philosophy. Something that could think in a manner as sophisticated as us and yet not question anything would be an organism which did nothing but survive mechanistically-not something we would be likely to call living or thinking very soon.

Although philosophizing is, in this significant sense, done by all of us, conscious enquiry into the nature of the cosmos is only performed by the philosopher. The cosmos is within us all in ways incomprehensible; the ultimate goal is to understand not it but to understand ourselves-and our own self will be the last thing to be understood. The true philosopher, I feel, is he who is simply unable to articulate why he philosophizes-all he knows is that there is within him an undying fire and thirst for knowledge and the truth. Of course, there is within all of us a certain degree of innate curiosity. All of us want answers to the big questions. Some of us just want them more badly than others do.

All of us philosophize, yes, but do not mistake it for a light after-snack activity. Philosophy marks the magnificent apotheosis of life itself; a climax which is the heightened state of intellectual intensity attained, and it happens unfortunately often that in this state the man is unable to contain and loses control over his own thought, stumbling on towards where he feels the truth lies, gibbering and drooling senselessly as he trudges onwards, forever approaching and never reaching: philosophizing has driven many a man insane by the intensity of his own thought. We must keep towards philosophy our thoughts true and our intentions pure and she will then show us the way, tugging us along ever so gently, occasionally giving us glimpses of her self. Only then can we seekers of truth finally obtain the mystical and open our eyes to the truth. As of now, we are, as Sir Isaac Newton quoth, merely children playing on the beach, occasionally finding a pebble more remarkable than others, while the vast oceans of truth lay undiscovered before us.

In this course, you and I, we shall learn to seek from her with humility; for we must not lurch on after her lustily but wade along in awe through the deep green mazes and forests she has made for us; and we shall then bask in her joyful radiance, wondering at the world around us. In this course, I shall attempt guide you truly through many fast-moving and dangerous rivers of thought. We shall begin by tracing the evolution of philosophy and then wonder at what it means to know something; I shall exposit on the meaning and basis of all human knowledge. This will be followed up by us thinking about thought itself: The meaning of this word we use so often, what gives it its transcendental feel and its limits. We shall wonder at these strange abilities of ours and what they mean; we shall wonder at the meaning of the word "truth" itself and consider the answers the collective philosophizing of humanity has given us so far.

Ethics and aesthetics I consider holy in nature. Them, we shall not speak of, but merely experience in the maelstrom of thought I will be pulling you through, for regardless of how hard you try to exclude them and speak purely analytically, the barren castle you attempt to build and its ground will, sooner or later, be infiltrated by the soft, seductive temptresses that are aesthetics and ethics.

So come take my hand, and let us begin.

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Aditya Dwarkesh is a 16-year-old from R. N. Podar School interested in and fascinated by literature, theoretical/modern physics and analytic philosophy with nothing by his side to guide him on these swampy, unused roads but an immense amount of intense curiosity.

Right through your Cranium

By Kiranbaskar Velmurugan

Cognitive science in itself is a very broad subject. There's Psychology, Philosophy, Neurobiology, etc. In this course I shall not delve into the Psychological part of Cognitive Science, but instead focus on some philosophical questions and see some bizarre phenomenon that revolve around our brain and mind. I will go into the debate between monism and dualism, and show some of the views and analysis on the topic.

Before we begin to discuss on the above topics, what is Cognitive Science? It's a science based on cognition. When I say a being has cognition, I'm saying that it can think, know and understand. Such terms are used in daily life quite often: "Did you know ... ", "I don't understand this." etc. However, on closer inspection, it is not clear what the concept of understanding or knowledge is. When can I say that I know something? Where in the brain is this concept understood? It might be tempting to try and map out the whole brain, neuron by neuron, in a computer maybe, and see how the brain works. But would this really work? When you think of a book, is there one single neuron in your head associated to the book? But this wouldn't make sense. If physical objects are mapped onto neurons, how do we humans do abstract mathematics? Moreover, the number of neurons in our brain is finite. There are far more objects than neurons.

What we just tried to do, trying to understand the mind by analyzing neuron by neuron behavior, is based on the belief that the whole is the sum of the parts. So to analyze anything, you simply break it down into its simpler parts and study those parts. This method is called reductionism. Clearly, this method would be inappropriate because on applying reductionism repeatedly, one could argue that atoms are conscious. Let me summarize it in a syllogism.

1. We are conscious.
2. We are made up of atoms.
3. Therefore, by reductionism, atoms must be conscious.

This unsettling conclusion really shows how purely using reductionism to study the brain is not correct. You see many examples in life about emergent properties.

1. Hydrogen (a combustible gas) and Oxygen (a supporter of combustion) combine to form water, which is capable of putting out flames.
2. "Swarming" is a common strategy in many animals. You see swarms of bees, flocks of birds, colonies of ants and herds of mammals.
3. When you see three trees next to each other, you see the separate trees, but when you see a thousand, you also see "a forest".

But notice this little speculation highlights one important question: “How is it that atoms that are not conscious, make up a conscious brain?”

This question shows how unintuitive the very nature of our consciousness is. You know that you are conscious. You are very sure of it. Yet, there’s no explanation as to how is it that this happened.

Since absolute reductionism fails, clearly there are emergent properties in the formation of our brain from neurons. True, we could stop at a certain level during our process of reductionism and point out that it is at this level that emergent properties start to pop out of the structures. But is it really that simple? Recall the example (3) given for emergent properties. Now think about the following question :

“At what point do just a mere collection of trees become a whole forest?”

How many trees would you need? This is just the problem with our approach. There are so many intermediary levels between the whole brain and neurons that it is not possible to point out the emergence of properties as a consequence of one particular level, this emergence is in a sense “fuzzy”. By the time you reach the whole brain level, the properties are there.

So do you consider the brain as a whole? You would think in this way you can make sure you encapsulate all kinds of emergent properties of the brain. But what has this helped us see? We now know that the brain in our head takes in stimulus and gives out nerve impulses. We are back where we started!

So we’ve seen that reductionism, the idea that the whole is the sum of its parts, doesn’t work to explain the brain. When we tried to consider the brain as a whole, we didn’t get more information about the brain. This method is called holism, as opposed to reductionism, saying that the whole is greater than the sum of its parts. But in the case of the brain, I think it’s more apt to say that the whole is completely different from the parts.

The point is that you cannot possibly try to explain the brain by considering only a single level of complexity at a time. You’ll need to take into account all the intermingling of the levels, the hierarchy, the relations, the functions to make a possibly complete model of the brain and the mind. Unless one resorts to such analysis, it shouldn’t be possible to make a proper and consistent theory of the brain.

Such are the nature of the ideas that I will explore in this course. I would diverge into many subtopics and there will be many questions which do not have a definite answer even today. There’ll be many experiments, analogies and illustrations along the way to make sure the subject at hand is explained better. I’ll make a short summary of it in the following paragraphs.

After differentiating between the mind and the brain, I will briefly talk about evolution and how it has changed the very way our brain works. Evolution is possibly the greatest and the most controversial scientific theory. Despite the numerous debates, evolution has numerous applications in many other fields of science. It has also shaped our brains to have some functions which provide some kind of a survival bonus. Thus, we can have some insight on the very structure of our brain by understanding evolution.

I will also talk about a theory of consciousness and try to speculate the existence of extraterrestrial intelligence somewhere else in the universe. We will have to think about on questions such as “What is intelligence?” and consider whether the intelligence we have is the only kind of intelligence possible or is it based on some global concept of intelligence, some grounded axioms that one must follow to be intelligent in any way. The concept of an “epiphenomenon” will also be discussed at some length.

Then I will look at the current status on the development of AI (Artificial Intelligence) and what is the motivation and objective of such endeavors. This will include the possible ways to represent a brain-like system in a machine and what representation is in itself. We will see how the “real” object is different from a “duplicate”. A common example for that would be:

1. Proof of a theorem written on paper and the proof represented as differently activated pixels on a monitor are both considered proofs for that theorem. Therefore, the representation of that proof is the same as the actual proof.
2. But, simulating a lake or an ocean with waves in a computer perfectly would not make it a “real” ocean as we know it’s just some bits being manipulated inside the computer.

This brings to the deeper and more general question : “What makes two things same, at what level of imitation does the imitation become the real thing itself?”

In my concluding articles I will talk about a theory known as “physicalism”, a kind of monism, and we will discuss about how well it fits within reality and how much it can explain without inconsistencies. We will also go into the limits of physicalism where I will shed some light onto what subjectivity and objectivity is.

Over this course, I hope to bring out some of the many mysteries that are still present in the field of Cognitive Science. The study of the brain and the mind is not a trivial one and has taken centuries to form as a subject starting from philosophy to the advance Neuroscience we have today.

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Kiranbaskar Velmurugan, a 15 year old from R.N. Podar school is deeply interested in subjects like Cognitive Science, Logic, Physics and Programming. Reading books on these topics to satisfy his curiosity has become a habit.

Koan-tum Mechanics

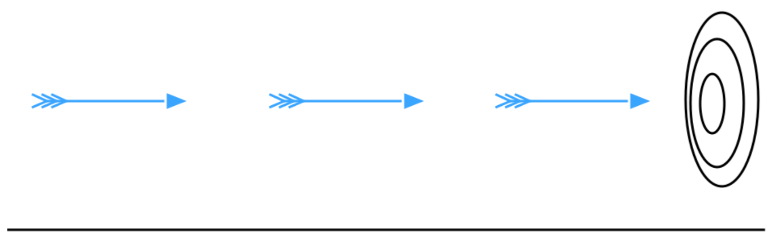
By Ameya Kunder

Everything that living things do can be understood in terms of the jiggling and wiggling of atoms . . .

-Richard P. Feynman

Picture yourself amidst the spectators of an archery competition. The archers are lined up in their respective lanes. The cue is given. They flex their bows and twang goes the bowstring. You watch the arrows moving at an exceedingly high speed as they pierce through the air and approach the target. The archer in lane 5 with his commendable dexterity has been able to hit a bullseye, thereby winning the championship! The crowd acclaims the winner. But pause for a while and go back to the instant when the arrow had just left the bow. Does the motion of the arrow that leaves the bow really exist or is it just a trickery of our perception?

Consider a point on the time axis (i.e. just a duration-less period of time).



Picture credits: Wikimedia Commons

At that point of time, the arrow which is supposedly perceived by us to be moving, is at rest. For example, if you start a stopwatch at the very moment the arrow is shot, and if you were to observe the position of the arrow after the 0.5 seconds have elapsed, you would notice that the arrow is at rest at that particular moment. Similarly, after 0.75 seconds have elapsed, in that certain time frame, the arrow is at rest too. At these specific instants, neither is the arrow moving towards the target (where the arrow is not present) as no time has elapsed, nor is it moving to where it is since it already is in that position. Hence, it can be safely said that at a particular point of time, there is no motion possible. We know that time is made up of an infinite collection of instants, and at every such instant, we have proved that the arrow is motionless. Therefore motion is impossible! This paradox is known as Zeno's arrow paradox. What appeared as a seemingly absurd question has slowly started to make sense.

But how is this paradox related to quantum mechanics? Quantum Zeno effect states that the stochastic evolution of a quantum state can be frozen if the measurements performed on it are frequent enough with respect to a given measurement apparatus.

The question that now arises is what a quantum state really is. What does it signify to perform a measurement on a quantum state? What does stochastic evolution of a quantum state mean? What does it imply to make frequent observations? And what aspect of the quantum state is to be measured by the apparatus?

Our main motive would be to address these questions and many more in the course that follows. I would like to make it extremely lucid that no prerequisite knowledge of quantum mechanics is required to follow this course. The quantum world is full of bizarre and surreal happenings. One must be geared up to face the fascinating and mentally taxing phenomena of this outlandish world. So let's explore this vast array of abnormalities!

Classical thoughts

Tennis balls being smashed, bullets getting shot, a top being spun, earth rotating around the sun etc. are few of the examples of bodies in motion whose movement we can perceive or whose movement's effects can be felt by us. The main purpose of classical mechanics is to study the motion of such bodies in accordance to a certain set of laws that govern them. In 1687, Newton published "Philosophiæ Naturalis Principia Mathematica" (Mathematical Principles of Natural Philosophy). It was a major breakthrough in the field of science since it contained the mathematical formulations of phenomena and forces that govern the motion of bodies in the universe. But were these laws governing the motion of macroscopic objects adequate to predict the motion of the tiniest of bodies, say, that of electrons?

Scientists in the early 1900s started to realize that these laws were insufficient and there was something beyond the scope of these rules that had yet not been discovered. Particles at the atomic level behaved starkly different from the macroscopic objects. Due to our senses being embedded in the classical world, it was really perplexing to get a hold of the quantum phenomena. Let's see what the real cause of this confusion was with the help of an experiment which has been rightly quoted 'to have in it the heart of quantum mechanics.'

Double-Slit Experiment

DISCLAIMER: What follows next might seem to be an ornate trick involving deception. But I ought to tell you that it has been performed many a times by scientists across the world, so you rather not doubt its veracity.

Take a bucket full of water. Tap on one end of the bucket with both your hands placed moderately close to each other so as to generate concentric wavy circles. What you would observe would be an intricate, beautiful pattern of waves interacting with each other. This pattern is known as the interference pattern.

We perform the same experiment but with a bit of a twist. Instead of physically tapping in a given medium, we use a monochromatic source of light (light wave of a particular wavelength or frequency), and shine it onto a screen containing two slits. Another plain screen (which can be thought of to be made of a kind of material which can detect the bumping of light waves or other objects onto it) is placed behind this screen so that all the light that passes through the first screen gets projected onto it. We observe that a pattern that we observed in the case of water is observed over here too. An interference pattern comprising of light and dark bands gets casted on the second screen.

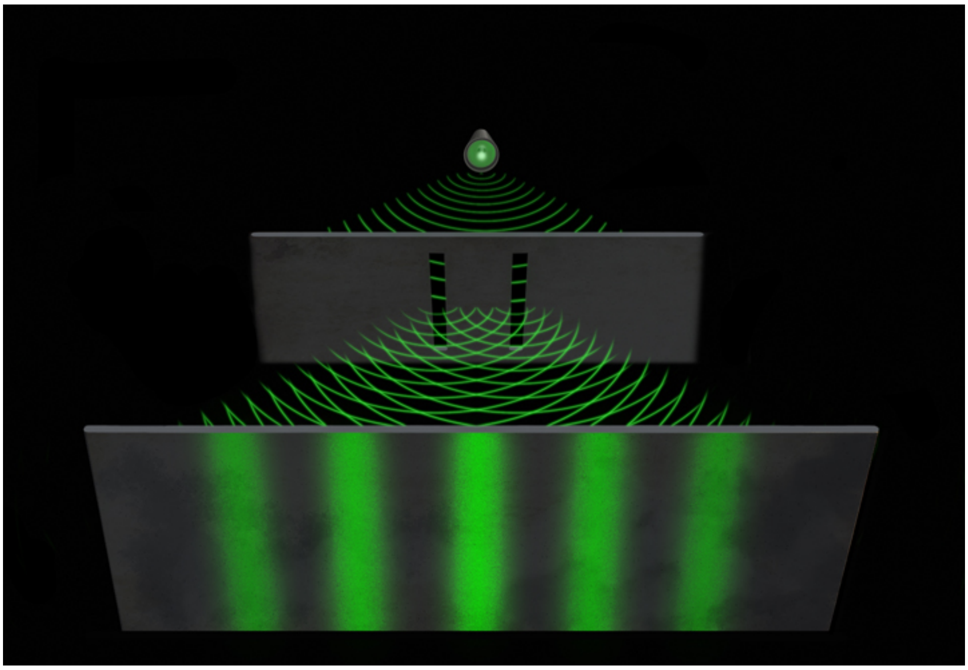
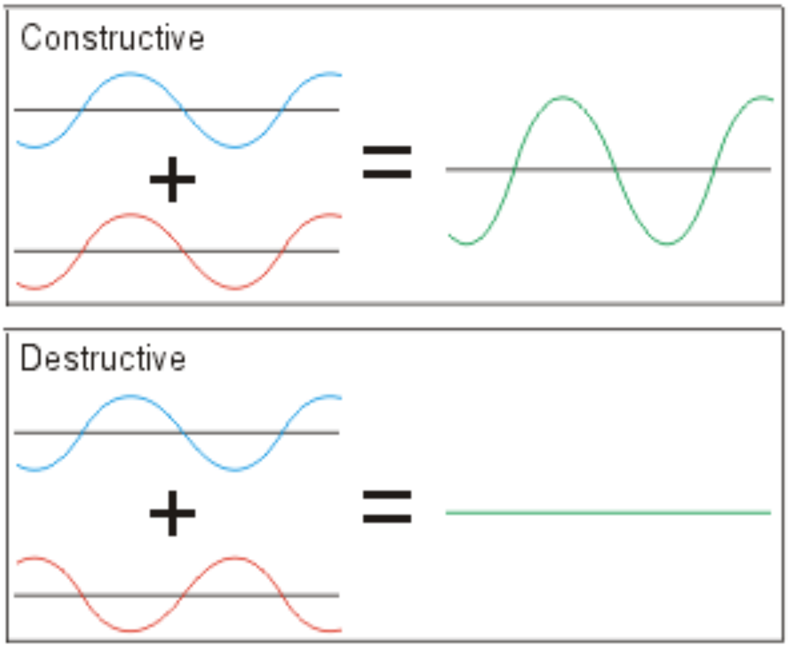


Fig: The interference pattern obtained when a beam of light is shone onto the screens.

But why does it happen so? A wave comprises of alternating crests and troughs which can be thought of to be peaks and valleys respectively. When the crest of one wave lines up with the crest of another wave or if the trough of one wave lines up with the trough of another, then a constructive interference is generated. This leads to the doubling up of intensity of the wave and leads to the casting of a dark, thick band.

But when the trough of one wave coincides with the crest of another or vice-versa, then they cancel out the effect of each other constructing a destructive interference. This wipes off the wave at that point.

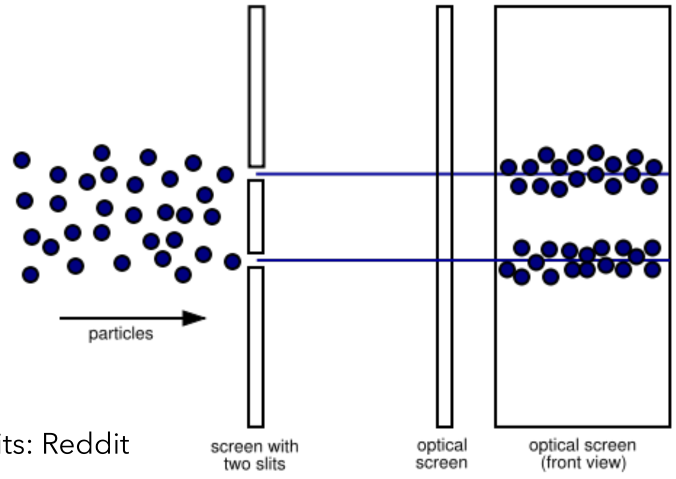


Picture credits: www.thinglink.com

Fig: Constructive and destructive interference

When light passes through the two slits, it splits into two waves and spreads out (owing to its property termed as diffraction). These two independent waves now interact with each other in the space between the two screens. The interaction leads to the formation of constructive and destructive interferences which in turn gets projected onto the screen in the form of light and dark bands.

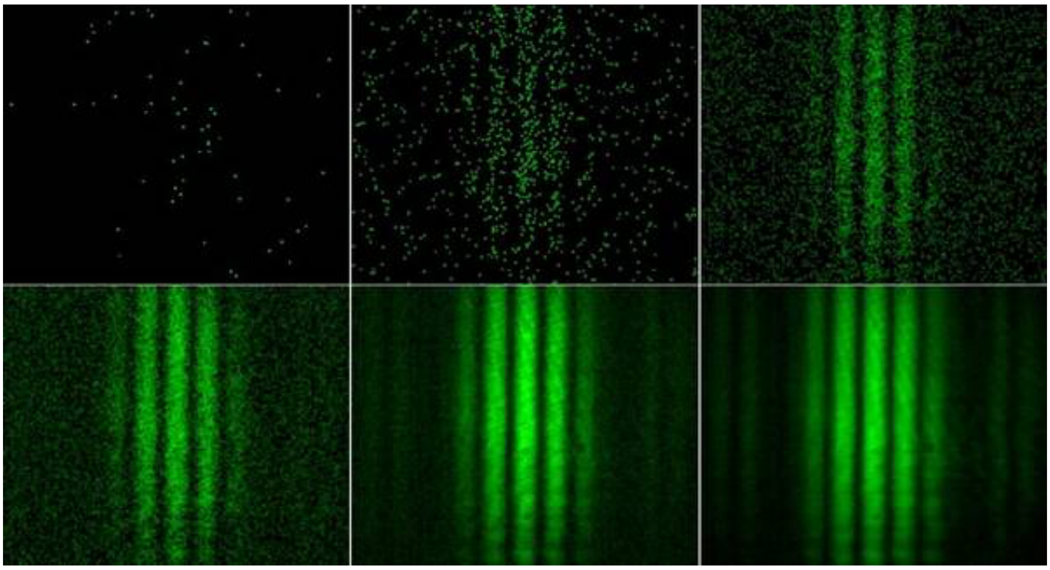
Let's take another case where we try to throw tennis balls at the same apparatus instead of shining a light beam (and yes, you do have to widen up the slits so that their width is a bit more than the diameter of a ball). Our senses implanted in the Newtonian (classical) world will effortlessly predict the result of this experiment i.e. a thick band of several dots made by the impact of the tennis balls with the screen would be formed behind each of the slits, appearing somewhat like this…



Picture credits: Reddit

Fig: Pattern obtained on the screen when Tennis balls are targeted onto the screens. One can think of the particles to behave like Tennis balls

Now we come to the most exciting part of the experiment. We conduct the same experiment but now with electrons. We shoot one electron at a time and wait for some time till a pattern can be observed on the second screen. An electron is a negatively charged particle that revolves around the nucleus of the atom. The nucleus is just a cluster of positively charged protons and neutrally charged neutrons located in the centre of the atom. The general portrayal of these sub-atomic particles is done in the form of spheres.



Picture credits: Swiss Physical Society

Fig: The interference pattern obtained when electrons are targeted onto the screen. Quite counter-intuitive as it may seem, they form a wave interference pattern than just forming two dark bands behind the two slits.

What you might now predict would be the same result as was acquired in the case of shooting tennis balls. In the beginning of this experiment, the electrons seem to make a pattern comprising of dots scattered around the screen in a random fashion. But as time progresses something rather queer is observed. We obtain a wave interference pattern which is quite similar to the one that we had received when we conducted the experiment with the light beam! What in the weird wide world made the electrons behave in such a bizarre way?

The dots made by the electrons suggests that they are but somewhat spherical objects similar to that of tennis balls, but the interference pattern suggests something entirely different- that they possess the wave nature. Which of the notions about the electron is really true? Is an electron neither a wave, nor a particle? Or is it both? Is there something beyond the scope of our knowledge that these electrons possess? Are the laws regulating the behavior of these bodies something completely diametrically opposite of what we have been believing?

'*Omne ignotum pro magnifico*' as Sherlock Holmes puts it. Does the grandeur of quantum mechanics really depend on it being unknown?

Illuminating the Koan-Cave

"One day Tokusan told his student Ganto, "I have two monks who have been here for many years. Go and examine them." Ganto picked up an axe and went to the hut where the two monks were meditating. He raised the axe, saying, "If you say a word I will cut off your heads; and if you do not say a word, I will also cut off your heads."

Both monks continued their meditation as if he had not spoken. Ganto dropped the axe and said, "You are true Zen students." He returned to Tokusan and related the incident. "I see your side well," Tokusan agreed, "but tell me, how is their side?" "Tozan may admit them," replied Ganto,"but they should not be admitted under Tokusan."

This is a classic example of a Zen Koan. Zen masters practising Zen philosophy narrate these koans to their students to test their progress on the path of enlightenment and make them advance on this trail. These koans are usually in the form of a short story, dialogue, statement or a question. They are counter-intuitive and are supposed to shine light upon the inadequacy of human logic. The masters believe that only by transcending dualism and logic can one attain true enlightenment.

Similar to these koans are the phenomena in the quantum realm. Extremely counter-intuitive and always ready to grapple with the common-sense in our heads. But similar to the koans, they even arouse a wide variety of thoughts in our minds. Hence, the title.

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Relatively Simple

By Pulkit Malhotra

Beautiful is what we see, More Beautiful is what we know, most Beautiful by far is what we don't"
- Nicolas Steno

Science has never been about giving the right answers, but rather about asking the right question. From "What makes this apple fall?" to "Is light a wave or a particle?" it has always been the great questions, that have driven science forward to explore the depths of the universe. In 1895, 16-year-old Albert Einstein had a great question in his mind; "What would it be like, to ride alongside a light beam?" A decade later, in his *annus mirabilis*, his answer would lay the foundation of the modern theory of gravitation and its concerned dynamics.

People can be classified into to two types: the theory-makers and the problem-solvers. Freeman Dyson in his paper, compares the two types, to birds and frogs. "Birds fly high in the air and survey broad vistas of mathematics out to the far horizon. They delight in concepts that unify our thinking and bring together diverse problems from different parts of the landscape. Frogs live in the mud below and see only the flowers that grow nearby. They delight in the details of particular objects, and they solve problems one at a time." says Dyson. Einstein was a bird. He didn't possess a liking for mathematics from his childhood (this was going to change drastically in the years to come). The mathematical details of his special theory of relativity were worked out by various people. One of whom was Einstein's university math professor, Hermann Minkowski (of the Minkowski space-time fame), who referred to Einstein as a "lazy dog" because of his disinterest in mathematics.

From Thales of Miletus (Father of Science) to modern physicists like Stephen Hawking, physics has covered a long journey through centuries. Physics has suffered a lot of ups and downs. From the downfall of the much beloved Newton's theory of gravitation to the rise of the spooky world of quantum mechanics. But despite all of this, this castle of physics has remained stable and held its guard.

It rests on 4 foundational blocks (the 4 fundamental forces - gravitational force, electromagnetic force, strong nuclear force, and weak nuclear force) one of these being gravity, laid down by Newton in his magnum opus, **Philosophiæ Naturalis Principia Mathematica** in the year 1675. It remained unshakeable for centuries to come. Time after time, People polished and cemented it, to make sure it retained its strength. But in 1905, it started to deviate. It was time to replace it by a new, better block. The man who took this job upon himself was Albert Einstein, a German-born Jewish third-class technical expert patent clerk, whose theory caused ripples in the world of physics, and whose impacts we still detect today.

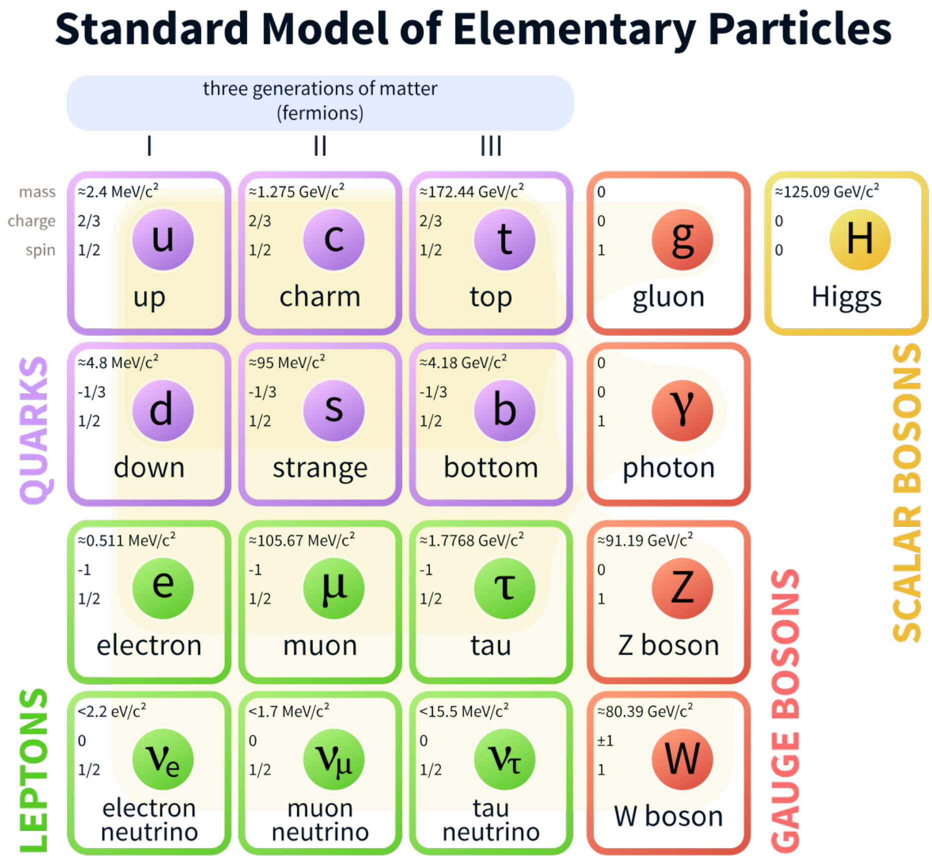


Fig: The four fundamental blocks immortalized in the Standard Model of physics.

In 1900, Lord Kelvin (after whom the standard unit of temperature is named) made a famous remark: *"There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."*

This is just 15 years before Einstein came out with his theory and changed everything we knew about space and time. To quote, the father of analytic philosophy and logician, Bertrand Russell:

"There have been four sorts of ages in the world's history. There have been ages when everybody thought they knew everything, ages when nobody thought they knew anything, ages when clever people thought they knew much and stupid people thought they knew little, and ages when stupid people thought they knew much and clever people thought they knew little. The first sort of age is one of stability, the second of slow decay, the third of progress, the fourth of disaster."

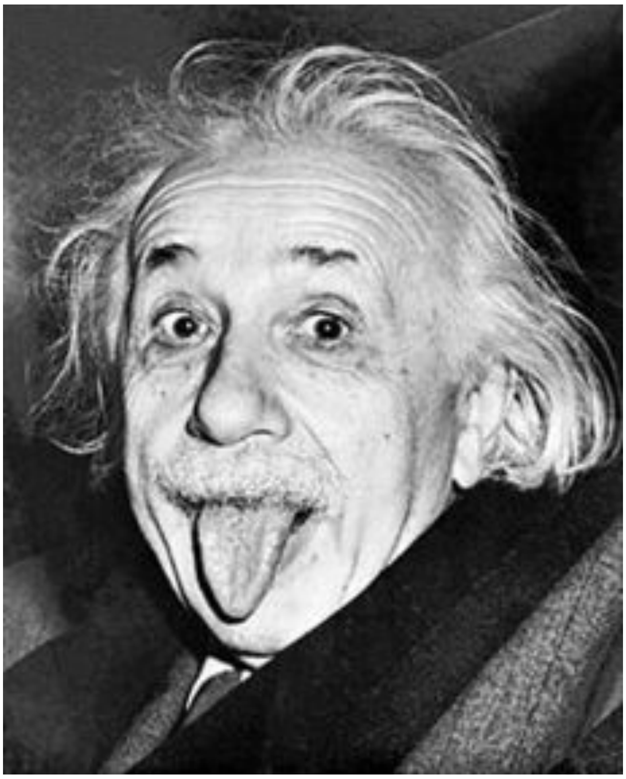
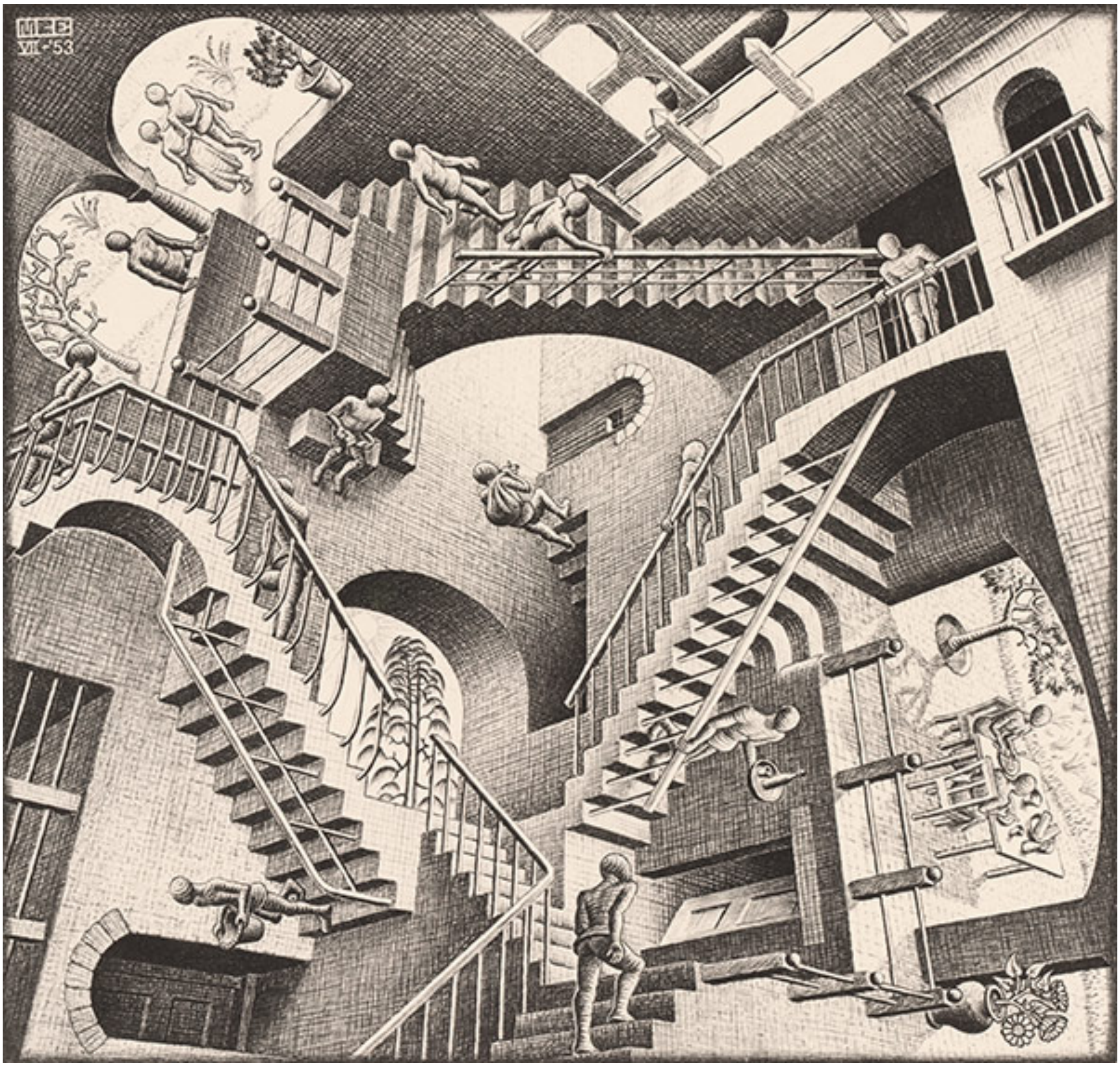


Fig: Although this famous image of Einstein was taken by United Press photographer Arthur Sasse in 1951, it would have been a fitting reply to Lord Kelvin's comment.

What is Relativity?

The natural question that must arise in the reader's mind, is that what exactly is relativity?
Every school child has read the overused quote by Einstein about relativity. "Put your hand on a hot stove for a minute, and it seems like an hour. Sit with a pretty girl for an hour, and it seems like a minute. That's relativity."

This is a good analogy but doesn't make matters very clear for the layman. Relativity is a simple concept. It means that everything is relative. But relative to what? In the world of relativity, the omnipotent, omniscient and omnipresent being is the observer. The world functions according to his will. The frame or the coordinate system the observer belongs to is called the frame of reference, or reference frame. Let's take the classic example of when you are sitting in a car. According to your reference frame, you're in rest but according to the man standing on the road, you're moving. So are you moving or are you at rest? The answer is at that you are doing both. You're moving if you consider the person standing in the road as the observer. You are at rest if you consider yourself as the observer. The man standing on the road is also moving (due to the motion of the Earth) with relation to the astronaut floating in outer space.



Relativity, by M. C. Escher (lithograph,1953).

This mind boggling masterpiece by the famous Dutch graphic artist, MC Escher portrays a world analogous to our relativistic world. Here what is the roof, and what is the floor? It is like motion in our world, changes from one observer to another. There is no one true roof and one true base. It is all relative.

To quote the Bible of Physics,

"The observer said let there be motion and there was motion".

Special and General Relativity

Relativity is divided into two parts -- Special and General. As the name suggests the first one is applicable for only a special case and the second one is the generalized version. The Special Theory of Relativity developed Einstein’s annus mirabilis, 1905, is for reference frames moving at uniform velocities to each other (Hence, the special case). It is important to note here, that it took Einstein 10 years to generalize his Special Theory. The difficulty arises from the devilish physical quantity known as acceleration. (It'll be a good exercise for the reader to think why acceleration causes such a pain in the neck). The General Theory of Relativity is for all reference frames, regardless of how they are moving to each other. When pressured by the press to give a simple explanation for the general theory of relativity, Einstein said,

“Time and space and gravitation have no separate existence from matter.”

These topics will be made clear in the articles to come.

Einstein's influence

Here is a paragraph from the hit Bob Dylan song, “Desolation Row”, where he pays a tribute to Einstein.

“Einstein, disguised as Robin Hood with his memories in a trunk
Passed this way an hour ago with his friend, a jealous monk
Now he looked so immaculately frightful as he bummed a cigarette
And he when off sniffing drainpipes and reciting the alphabet
You would not think to look at him, but he was famous long ago
For playing the electric violin on Desolation Row”

Here Bob Dylan makes several clever references.

One of the several interpretations is that the “jealous monk” is Sir Isaac Newton, whose theory was replaced by Einstein's. The third line is a reference to his disheveled, famous appearance with his iconic helter-skelter hair. The bummed cigarette refers to Einstein's love for pipes. The “off sniffing drainpipes” is a reference to black holes, which were predicted by his general theory of relativity and “reciting the alphabet” is about his famous equation, *E=mc^2*. The last line’s “electric violin” is about his well-known love for violins.

This is only one of the few ways to express Einstein's huge impact not only in physics but also in pop culture.

Why Einstein?

The problem in science has not been to come up with new theories, it has been to break away the shackles of the old theories to make place for the new ones.

Before Einstein, a lot of people came close to the discovery of Special relativity. Famous geometer and Einstein's inspiration, Henri Poincaré and Hendrik Lorentz (who later worked out the mathematics of the special relativity) came just one leap far from discovering the theory but pulled back because of their great love for the good ol' Newtonian theory. Einstein was a rebel, and a true radical at heart. His love for finding the true principle of the universe was greater than his love for the old ones.

When Einstein's son, Eduard asked him about why he is so famous, Einstein wittingly replied

"When a blind beetle crawls over the surface of a curved branch, it doesn't notice that the track it has covered is indeed curved. I was lucky enough to notice what the beetle didn't notice."

Einstein's theory is one of the keystones of modern physics. Understanding it, is an achievement in itself. There was a time when only a few men in the world could comprehend Einstein's work. There is a famous anecdote about Sir Arthur Eddington, where when asked by a reporter about the three people in the world who could truly understand the theory of relativity, Sir Eddington answers that he was only thinking who the second person could be This journey would be filled with exciting revelations into the cosmos, but I would like to tell you in advance that there are parts of this theory that are not known, and perhaps would never be known, *ignoramus et ignorabimus*. My advice to the reader is to stay curious and remain enthusiastic, or as the master himself said;

"I have no special talent. I am only passionately curious."

-Albert Einstein

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Pulkit Malhotra is a student of RN Podar School. He has a long standing interest in theoretical physics and wants to pursue that field further. He is interested in the deep secrets of the cosmos and their philosophical implications.