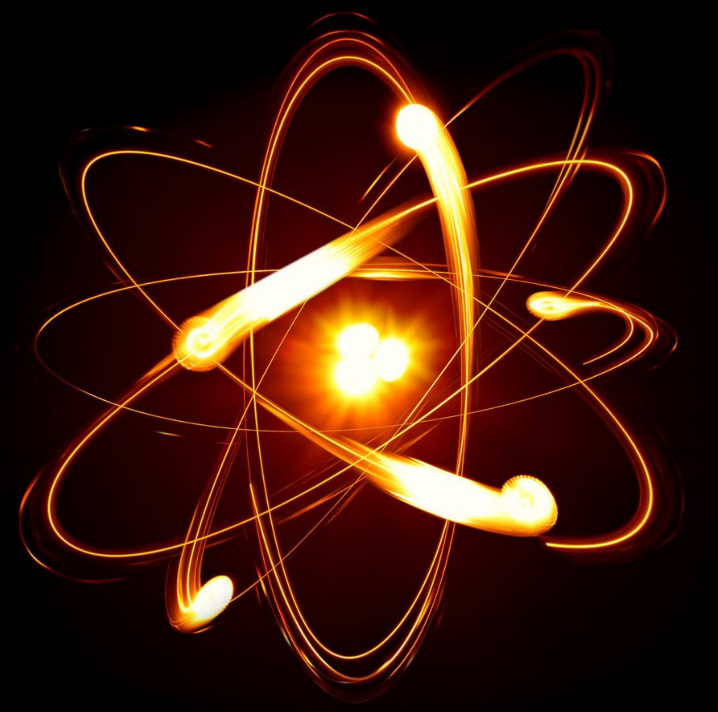
ECHO



2019

PhySoc
Physics Department

AD DEI GLORIAM
St. Stephen's College, Delhi

The Team

Chief Editors	Sukhveen Kaur Vivin Vinod
Copy Editors	Michelle Mathew Reuel Dsouza
Cover Page & Layout	Vivin Vinod
Art Editors	Aashiya Anitha Shaji Mahak Sadhwani Neel Lohit Dash
Reporters	Aanchal Mahak Rishab Jain

It gives me immense pleasure and satisfaction to finally pen down the editorial for the Physics Journal “Echo” 2018-19.

From requesting for articles, extending deadlines, interacting with the alumni to finally compiling the journal, it has been a great journey working with my co-editor Vivin and the Journal team.

On a personal note, I encourage all the undergrad readers to write for the upcoming editions of the Journal. It gives you a platform to share your passion for science. If you have come across an intriguing concept, write about it. Or you can pick up any model and work upon it. One should begin answering questions involving the “Physics” of the system and then move on to mathematical analysis. Conveying the physical analysis of even the simplest model is a tricky job. I am sure writing about it and your ideas will help you develop a research oriented and creative mindset.

I express my sincere gratitude to our staff advisor Dr. Sangeeta Sachdeva for her constant support and guidance. I thank the members of the Journal team for consistently working for the successful completion of this journal. Many thanks to all those who contributed to the journal in the form articles and pictures, without whom the Journal wouldn’t have taken its present form.

The journey of Echo began in 2012 with the aim of encouraging scientific reasoning among students. I hope its journey continues with an increased number of articles from our undergrad readers.

Happy reading!

- **Sukhveen Kaur**

raison d'être

Life is a series of choices that last a moment but have consequences that echo for a lifetime, if not longer. The years that you spend in college are a fundamental part of this choice-consequence paradigm. A paradigm that takes you by surprise, because more often than not, you never had had to make these choices. It was your parents, your teachers, or maybe your nosy relatives who made these decisions for you. All of a sudden, the power of decision making is thrust into your hands. Some excel at this. Others fall prey to its ‘stress lines’.

Somewhere between these choices and trying to ‘act your age’ you get lost among the plethora of relative absolutes. Somewhere down the line you trip on your own feet. Now, this is crucial. What do you do next? Do you roll around and get dirty? Or do you jump up, dust yourself off – no wait, what am I thinking? This almost never works! If there is something I have learned in three years of college, it is that it is usually good to roll around for a while, assess your situation and then propose a plan-of-action to stand up and dust yourself (all this at the risk of sounding preachy). This might not be the suggested scenario for all the issues though.

It is a delicate balance between taking risks to make your own choices and not making one that you might regret. At the same time, getting stuck in limbo is a fair chance. With life comes a lot of uncertainty, but it is these uncertainties that make all the difference. What makes life worth tackling is the unpredictability it offers. The non-linearity is a glimmer of hope at finding a non-monotonous pathway to something better each day. Life is a mixed bag, sure, a bag of balls not just the red and black. A typical probability experiment albeit the probability is always unknown for most part. One finds true joy in living in the moment (again, at the risk of sounding cliché) and in taking life as it comes. Step back, try to envision that bigger picture, of course you won’t see it. But stand up, take that calculated risky jump and see where you land.

What if I fall? Oh, but dear, what if you fly?

- **Vivin Vinod**

(Editor)

PħySoc

CONTENTS

FROM THE STAFF ADVISOR

-DR SANGEETA SACHDEVA

Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.

- ***Kofi Annan***

The Physics Society of St. Stephen's College completely believes in this idea and provides a platform for students to share, impart, communicate, learn, deliberate, reflect and ponder over information gathered through their educational background and training and empowers each member of the society with knowledge. Created a long time ago with a modest outlook, it has flourished with the zeal, passion and enthusiasm of students to envelop wide range of activities from talks to paper presentations, from problem solving to sky viewing, from lecture series to physics trips etc. The society adds another dimension to the life of the physics students where they are not restricted by the boundaries of syllabus, overwhelmed by their professors and burdened by the demand of a system. It allows them to soar, explore and be the budding physicist that they would want to become.

The Physics Society Journal is another genre through which the students can express and convey new thoughts, philosophies and progress in the field of physics but somehow it has not become an integrated part of the society and marks its presence occasionally. To overcome many hurdles and to ensure the easy availability and accessibility to every member of the society, we are starting with the e-journal. Hope this would become a regular and essential feature of the society.

I congratulate the entire team who has worked hard to put this together and wish them the best. I, also encourage every member of the physics department to participate and contribute towards the society so that it continues to swell and grow.

Individual commitment to a group effort - that is what makes a team work, a company work, a society work, a civilization work.

- ***Vince Lombardi***

THE ART OF *NOT* UNDERSTANDING, SKILLFULLY

-DR BIKRAM PHOOKUN

Try again. Fail again. Fail better.

- ***Samuel Beckett***

One of the things I like about physics is that it is such a rich source of metaphors. In this essay I'd like to talk about one that has been on my mind in various forms for a while – but let me come to it indirectly.

If you ask a typical physics undergraduate audience what they get from a technical talk by a visiting scientist, they will, if they're far enough from one their teachers to speak freely, say that they get nothing, they only attend to please the advisor to the physics society. (It is perhaps in acknowledgement of this that the caring speaker will often begin his talk with the words "Please stop me at any moment if there is *anything* you don't understand.")

Hidden in the students' protestations and the speakers' kindness is an assumption about comprehension – that it happens element by element. This is not invalid, and works well when all that is asked of you is that you *cover* a distance. So, for example, if you are trying to determine the length of a tortuous path up a mountain, you have to cover it sequentially, measuring ever step (or allowing one's GPS to do the same), to determine the length. This is how, for example, we put together sounds to produce words: C-A-T cat. It is also the way many children's stories are constructed.

I read *The Three Musketeers* by Alexandre Dumas a couple of years ago, and of course I enjoyed it, but I kept thinking that I would have enjoyed it much more if I had read it as a child. The reason, I figured, was the way the story was constructed: a scene would be open, unfold, and then close, before another began. The architecture of the story is fundamentally simple: each episode is added to the previous one, and by the time you reach the end you've read and understood everything that the story has to offer. This architecture is similar to that of most movies, for example, in which each scene is a simple continuation of the previous one. Surprises don't in any way change the architecture; a surprise is like a rupture in the path, and once you have crossed it you keep moving ahead.

Let us contrast the experience of reading a children's book with that of reading a difficult poem. You read the whole poem, and it makes no sense to you: it seems to be a succession of words without meaning. You say to yourself, ``I don't get it'', and, usually, you give up.

Let us see what happens if you don't give up. You read the whole poem, and it makes no sense to you. You read it again, and you begin to hear the rhythm of the language and the rhymes that the poet has decided to use, though the words are still a galimatias. You read it again, and the fragments that you understand begin to connect into complex, articulated, structures recognizable as sentences, but they still don't make sense. You read it again, and the sentences become sense-bearing entities. You read it again, and some of the words strike a chord, you look them up, and realize they're allusions to something else that you read last year. You read it again, and you begin to see how what comes later in the poem modifies that which came earlier and which you understood differently the first time you encountered it, as if the sense of the poem unfolded not just forward but backward as well. You read it again, …. You put away the poem, and you read it again later – and now all that you discovered about it in successive readings, and that has now receded into the periphery of your consciousness, comes together as you go through the text; the various layers of sense that you perceived are integrated. But the process of integration is also one of a certain kind of forgetting – the less graspable elements of sense recede into the background, so that you are no longer conscious of them. They form a kind of inner environment, or terrain, within which the words, which now all seem to make sense, find meaning. So, when you now read the poem, you may seem to be moving from word to word in the same way as when you first encountered them, apparently understanding them sequentially, but what is happening is that you are really striking the words like notes on a piece of music, so that what you get is much more than the succession of words.

The layers of meaning that I speak of may not enter into your comprehension in the order mentioned above, but *all* the layers contribute to the meaning of the poem. There is a famous nonsense poem by Lewis Carroll called *Jabberwocky*, which contains only the first two layers. The sentences are grammatically correct but carry no sense; yet so skilfully have the first two layers been constructed that when you read the poem you keep getting the feeling that you understand *something*. And in fact, you have understood something, or rather you have become familiar with something – the terrain on which sense could have been constructed. This terrain, which we tend to forget once we become completely familiar with it, reappears when we try to learn something difficult, for example a foreign language.

In the childish way of understanding – which is always active, even in the presence of the second – you stack atoms of sense to construct the whole, but go no further. In the more adult way of understanding that I speak of – which certainly happens intuitively, but improves with training – you superpose layers of sense to construct whole.

If this sounds mysterious, think of what happens when you download an image on WhatsApp. What you first see is a blurred image; once you click on Download the image becomes clearer. In fact, if you download a large image on your computer, you may find that it goes through several such stages: at every stage the entire image is on your screen, but it gets less and less blurred as the download progresses. At every stage the entire image, in terms of spatial extent, is there; what happens is that the resolution – the clarity – increases: you get a more and more fine-grained image. Contrast this with another possible way of downloading images, in which the image is downloaded pixel by pixel, each with all the detail in contains.

The pixel-by-pixel approach – to the comprehension of stories, poems, arguments, theories – is necessary, but by itself it is naïve. It is the right way to begin the journey into understanding, but with it alone you will find it difficult to make progress with most interesting and meaningful stories.

A typical story in physics is subtle, profound, and difficult to understand. It slows you down. You have to read it the way you read a difficult poem. When you listen to an unfamiliar story, as in a talk by a visitor, what you hear and seems often like a nonsense poem. The skill of a speaker can lie to some extent in being able to do what Lewis Carroll did in *Jabberwocky* – carry the audience along even when they don’t understand much, so that they want to return and look for fuller meaning in what he or she said.

What happens in a talk can also happen to some extent when you read an argument in a physics textbook for the first time. The sense that the argument carries will reveal itself to you only if you are able to superpose on your fuzzy initial understanding the more fine-grained layers of meaning that the text contains. But for this to happen, you must allow yourself to accept, when you first perceive them, the lower, more coarse-grained layers. This may seem dishonest, as if you were willing to accept something without understanding it, but it is not, so long as you accept it provisionally, as you accept the blurred image you first get on WhatsApp, knowing that it will reveal itself fully only when the details are added.

What WhatsApp does before transmitting an image is to take its Fourier transform (or something related to it). The beauty of this is that it automatically decomposes the image into a stack of images each spatially complete. Each image, or layer, differs from the others in the level of detail to which it is tuned. So for example, if the image is that of a wrinkled face, the layer at the lowest level of resolution will show a blob with no sharp edges or details, the next will begin to show contours likes the jawline and details like the eyes and nose, and so on, until the one with the highest level of resolution will show the wrinkles; when all of these layers are added together, the original is reconstructed. (It is customary these days to "improve" one's photos by blurring out blemishes until they meld in with the surroundings. A smarter way to do the same thing is to take the Fourier transform of the photograph, remove the layers with the highest resolution, and use the remaining ones to construct an "improved'' image; in fact, radio astronomers do this kind of image processing regularly.)

Artificial Intelligence, Free-Will, Physics and All That Useless Ruminations

Patrick Das Gupta
*Department of Physics and Astrophysics, University of Delhi, Delhi - 110 007 (India)**

Introduction

Is the Age of Artificial Intelligence round the corner? Currently, what is evident is the hectic use of machine learning in various pattern recognition tasks - be it face and voice identification, or classification/selection of biological and astronomical entities. After all, who has not tried the Iphone's 'Hey Siri' voice recognition app? Of course, it is the need of analysing sheer volume of data that is forcing one to use such Artificial Intelligence (AI) driven algorithms in conjunction with high speed computers.

In fact, plans to deploy machine learning strategies to sift through humongous quantity of data is underway in order to select specific sub-atomic particle tracks in particle accelerators such as the Large Hadron Collider at CERN, Geneva, to look for Physics Beyond the Standard Model. The motto seems to be: Find evidence of new physics by making 'intelligent' algorithms first learn what to keep, what to discard (i.e. high energy particle track patterns in the array of detectors) and then unleash these computing 'slaves' on zillions of experimental data emerging incessantly out of an accelerator (during its science-run).

Free-will

Thank God, these 'soft-e-robots' have not yet developed a free-will of their own! Else, we would soon witness a revolt of the computing-kind. But wait a minute, do human beings possess free-will? To deal with this question we have to delve on the notion of free-will first. It is a common observation that people do not behave like machines. In the case of a machine, in general, one can predict the output with great certainty, given an input. The industrial age essentially relied on this mechanical determinism. Nowadays, we have devices (e.g. washing machines) available in the market that are endowed with 'fuzzy' logic in which the old determinism of classical machines is a little bit fuzzy.

On the other hand, a person facing a situation that requires her/him to make a choice, does exercise her/his options (seemingly) with full freedom before zeroing on to a particular decision. The final choice made is based on several internal and external factors. It is also perceived that greater the learning of an individual, larger is the world of options and therefore, freer is the will that makes an informed choice. Now, given identical circumstances, separate individuals may (and are likely to) opt for distinct choices. Such disparate behavior perhaps can be explained by invoking differences in the internal factors (nurture, IQ, EQ, knowledge, hormones, genetic predisposition, etc.) inherently present.

A question that is germane to this discussion is: Can a human being decide to act at WILL, impervious to external factors? Many of us would say, yes. However, some neuro-scientists, based on the outcome of their experiments, think otherwise. For instance, several subjects taking part in an experiment were shown five white circles appearing on their respective computer monitors, and were told that one of the white circles would quickly turn red in colour, and that each of them would have to guess fast which one would turn red before it actually does [1]. What the subjects were not informed was that a computer program, associated with the experiment, chose at random a circle that would turn red.

The outcome of the experiment was rather surprising. Particularly when the time interval between seeing the 5 white circles and guessing which one would turn red was very short. Instead of the expected 1/5 probability of a successful guess, the observed success rate actually corresponded to a probability of more than 3/10. According to the neuroscientists who designed the experiment, it is likely that often the subjects picked the circle AFTER it had turned red, although they genuinely believed that it was their wilful apriori guess [1]. To put it differently, apparently the brain had exchanged the time order of seeing and guessing.

So, were their brains tricking the subjects to believe that their choice was an act of free-will, and not prejudiced by the event that had already taken place? Certainly a very interesting possibility. Is this how people get hypnotised or brain-washed, led by strong stimuli from a hypnotiser? Of course, more research in the field of neuroscience is needed before our minds are tricked into believing the above conclusion that is based on the 'circular' experiment.

Thermodynamics, Quantum Theory and Mind

Speaking of free-will, what about our understanding that 'thinking' is merely an activity of the brain wherein myriads of feeble electrochemical impulses fire across the synapses between neurons? But a brain is just a living tissue made of neurons, dendrites, axons, etc. which in turn are composed of atoms and molecules. Hence, must not 'thinking' then be deterministic, governed eventually by the fundamental laws of physics?

Well, living systems in general and brains, in particular, are actually open thermodynamic systems, exchanging energy and matter with the environment, and are definitely not in statistical equilibrium. The atoms and molecules therein, whose number exceed the Avogadro number $\approx 6 \times 10^{23}$, execute tiny random motions. Therefore, it is next to impossible to apply fundamental laws of physics to each such microscopic entities that are coupled to each other in order to forecast their individual evolution in time. It is somewhat like asking one to quantitatively explain the functioning of a launched spacecraft like Chandrayaan, starting from basic principles of quantum mechanics.

Thermodynamic fluctuations are generic in such macroscopic bodies unless they are maintained at ultra-low temperatures close to absolute zero degree-Kelvin. Thus, even though the physical processes in a human brain may follow a well defined and predictable path on an average, random statistical fluctuations may lead to our consciousness demonstrating genuine free-will. A radical proposal has been advanced by the brilliant physicist-cum-mathematician, Roger Penrose, to explain consciousness in which the author invokes quantum-coherent state akin to a Bose-Einstein condensate (of microtubules in the brain) on scales covering an appreciable portion of the brain [2].

In this point of view, free-will can of course emerge spontaneously as a result of the collapse of a initial quantum state describing the microtubules to some other state, the outcome being totally unpredictable, a hallmark of the quantum indeterminism. Only experiments would tell us whether Penrose's theory of quantum consciousness is vindicated in the future.

Complex Systems and Life

While one can be unequivocal in stating that no biological system violates physical laws, it is altogether another matter trying to describe the behaviour of a living body from first principles. Such an exercise obviously is a Herculean task if not plain impossible. The manner in which a living organism (e.g. amoeba) reacts to environmental stimuli, manipulates the ambient resources actively and proliferates, instills a sense of wonder and mystery. More so because it does all that while being within the ambit of laws of physics. It is as though life has a will of its own that transcends the natural course of events ordained by fundamental laws.

Can a system consisting of a handful of atoms and molecules constitute a living entity? My reflections on this question are as follows. Consider, for instance, the behaviour of an organism when (a) there is a speck of food nearby or (b) a toxic substance introduced very close to the body. It is obvious that unless this specimen is highly mutated, (a) will cause the living organism to approach the grain of food, while (b) will lead to its beating a hasty retreat. In other words, in most situations, such simple living systems display predictable behaviour (essentially for the sake of survival).

Then, we may argue that a small number of atoms or molecules interacting with each other in a coherent manner can never represent a living system. This is because although the dynamics of such a system S_1 will be governed by the Schrodinger equation, incessant interaction of S_1 with the environment would lead to frequent random collapse of the wavefunction describing the state of S_1. Clearly, a simple system such as S_1 cannot behave like a living entity. Living organisms need to be of macroscopic size - consisting of more than Avogrado number of molecules.

Therefore, a living body with all its innate properties of survival, reacting to external stimuli, multiplication, etc. needs to be a complex system - a system of macroscopic size made of standard matter but has many interconnected departments analogous to what exists in a large business organization, constantly exchanging information/signals with each other, as well as sensing the external environment so as to manipulate and take advantage of the available resources.

Life displays an apparent purpose - an emergent behaviour of a complex physical system in order to survive against all odds and multiply, so that it fills up the space and time with similar copies of itself. The physical nature of genetic material is such that there is a propensity towards generating more and more copies of the genes using matter and energy available in the environment. Living entities create order locally, leading to the decrease in entropy within. Since, the second law of thermodynamics remains invincible, entropy outside keeps increasing along with an increase in the order within the living organisms as they continue to survive and procreate.

Robots, Aesthetics and Mathematics

Can a robot endowed with AI appreciate music or fine arts? Can it prove hard mathematical theorems and create new mathematics? Let us first ask why do we like to listen to music or stare had great sculptures or paintings. It is possible that the combination of certain musical notes that a few pre-historic ancestors of ours got attracted to, were similar to the natural sounds of a koel or a nightingale or some other song-bird. This accidental instinct of getting drawn to the 'avian melody' increased the survival probability of these ancestors, as it led them to newer pastures and fertile land where food and water were readily available, for birds too flock around verdant regions.

Perhaps appreciation of music and art is hard wired in our brain. The string of notes that is similar to the chirping of a song-bird gives us pleasure because of its mental association with spring, flora, water, finding a mate, etc. dating back to early ancestor's struggle for survival when she/he was a hunter-gatherer. Our fondness for colour and visual aesthetics is possibly linked with early person's instinct to quickly spot fruits of different hues, lush green vegetation, crystal blue rivers or predatory animals hiding behind wild bushes, for her/his own survival. In other words, it is likely that, at a very basic level, appreciation of music and art provided an advantage to a majority of human beings in the struggle for existence in the pre-historic times.

What about abstract mathematics? Early mathematics like geometry and arithmetic were based on perception of shapes and counting. They were useful in day-to-day practices. The real world continues to inspire mathematicians, whether one considers invention of calculus in order to explain trajectories of celestial bodies or birth of theory of probability from systematic analysis of gambling outcomes. Speaking lightly, Yudhisthira, eldest of the Pandavas, could have outmanoeuvred Shakuni in the game of dice had he been familiar with the theory of chances.

Did the chance coincidence of angular size of sun and moon being equal at the present, causing thereby awe inspiring eclipses play an important role in the development of mathematics. It is to be noted that renowned mathematicians like Hipparchus, Aryabhatta and Varahamihira were preoccupied in developing mathematical techniques to explain as well as predict eclipses. Perhaps in the absence of moon occulting the sun in an imagined world, impetus and motivation to develop trigonometry and other computational techniques would be missing.

Of course, with time mathematics became more and more abstract. It developed wings of its own that was based more on beauty and elegance, and less on the tangible world around us. But the surprising thing was that abstract mathematics invented for reasons of aesthetics at times turned out to be language of fundamental physics. So much so, that an eminent physicist Eugene Wigner wondered about 'The unreasonable effectiveness of mathematics in the Natural sciences' [3].

Given the lack of such evolutionary and survival needs, as far as AI is concerned, one wonders whether robots passing the Turing Test can create novel mathematics and original aesthetics in the distant future. In the Age of AI, would they have free-will? It appears to me that existence of free-will is substantiated by individuals who, against all odds, demonstrate creativity by generating absolutely original products. What is magical in it is this: A conglomeration of atoms and molecules coming together to willfully create an innovative structure made of atoms and molecules, all under the purview of physical laws.

Can AI attain such creativity? When will an robot proclaim (like Descartes): 'I think, therefore I am.'? It is obvious that the Age of Internet transformed the functioning of the world and the society in a spectacular way. Such a metamorphosis was certainly not predicted 40 years back. What impact would an Age of AI have on our lives? Perhaps when intelligent as well as ethical human beings and AI work in tandem, the pace of new discoveries and innovations will skyrocket. Only future can tell us.

Acknowledgements

I thank Tarun Deep Saini, Satyaki Bhattacharya and Abhinandan Dass for their helpful comments.

References

[1] https://blogs.scientificamerican.com/mind-guest-blog/what-neuroscience-says-about-free-will/
[2] Roger Penrose, 'Shadows of the Mind' (Oxford University Press Inc., New York, 1994)
[3] Patrick Das Gupta, 'Mathemagical 2014 - An Indian Perspective', arXiv:1508.06988v2 [physics.hist-ph]

---

* Electronic address: `patrickdasgupta@physics.du.ac.in`

चलो सुनते हैं मंज़िल और सफ़र की कहानी।

- विपिन चौधरी

चलो सुनते हैं मंज़िल और सफ़र की कहानी।
एक मुसाफ़िर था मगर राह बड़ी अनजानी,
हर सफ़र बीतता गया क्योंकि मुसाफ़िर ने मंज़िल को पाने की ठानी
पर जब मंज़िल ना मिली तो उसे लगा कि उसकी किस्मत ने की बेईमानी।।
हाँ कुछ ऐसी ही होती है मंज़िल और सफ़र की कहानी।।

यूँ तो हर सफ़र एक मंज़िल की ओर जाता है,
मगर बीतते-बीतते कितने अपनों को पीछे छोड़ जाता है।
कभी-कभी सपनों की चाह में इंसान अपनों से मुकर जाता है,
यूँ तो हर सफ़र एक मंज़िल की ओर जाता है।।

आसान नहीं होता कोई भी सफ़र, हर पल रहती है मंज़िल की फ़िकर।
वक़्त बीतता जाता है और पूरी हो जाती है जीने की उमर,
शायद इसीलिए आसान नहीं होता कोई भी सफ़र।।

फिर कैसे मुमकिन है सफ़र को जीकर मंज़िल को पाना?...
मैंने सभी से पूछा मगर ये सवाल बड़ा ही अनजाना।
मेरे हर सवाल का जवाब मेरी माँ देती है,
तो चलो सुनते हैं कि माँ क्या कहती है।।

मंज़िल से ज़्यादा सफ़र ख़ूबसूरत होता है

और इस सफ़र मे अपनों का साथ कान्हा की मूरत होता है।

यक़ीनन मंज़िल को मिलना ही होगा एक दिन

मगर सफ़र बीत रहा है मुसाफ़िर तू ज़रा अंगुलियों पे तो गिन।

कल ना ये मुसाफ़िर होंगे और ना ये राह दिखाने वाले,

सिर्फ़ तुम और तुम्हारी मंज़िल रह जाओगे अकेले जीवन जीने वाले।

ख़ुशियाँ तो होंगी मगर किसके साथ बाँटोगे,

होंगे ग़म भी क्या सब अकेले सह लोगे।।

माना की ज़िंदगी में लोग आते और जाते हैं,

कुछ लोग जीना सिखाते हैं तो कुछ लोग सताते हैं।

मगर सच यही है कि जाने-अनजाने वही लोग हमें हमारी मंज़िल तक पहुँचाते हैं।

माना कि ज़िंदगी में लोग आते और जाते हैं।।

ऐ मुसाफ़िर, तू ज़िंदगी जीता चल सबके साथ-साथ कदम तो रख,

फ़िक्रना कर हर सफ़र पहुँचायेगा तुझे तेरी मंज़िल तक।

सफर की कीमत समझोगे तो मंज़िल खुद मिल जायेगी,

ज़िंदगी एक बार मिली है फ़िर कभी ना मिल पायेगी।

एक लम्हे को जीकर सालों तक याद करोगे,

जब मंज़िल मिल जायेगी तो इन्ही लम्हों की बात करोगे।।

हाँ शायद इतनी-सी ही होती है मंज़िल और सफ़र की कहानी

मगर इस सफ़र पे चलकर हम सबको है ज़िंदगी बितानी।

तो क्यों ना जी लें सफ़र को ताकि मंज़िल मिल जाये,

अपना-सा मानें हर मुसाफ़िर को ताकि हर गिला मिट जाये।।

हाँ इतनी-सी ही होती है मंज़िल और सफ़र की कहानी।।

Just another Yuletide

Mitrajyoti Ghosh

January 14, 2019

"You don't need to know Chemistry to know how to bake a good cookie - that's effective field theory!".

The gingerbread cookies had just come out of the oven, and Naomi stared at the fresh batch, content with what she had just said. She was a string theorist, and she still used $\vec{F}_G = G\frac{mM}{r^2}\hat{r}$ to compute the gravitational force between two distant objects. The proposed grand theory of gravity had not really put an end to Newton's regency, it had been kind enough to grant him a patch in the physics-verse where his words would still be as good as God. Likewise, the wonderful baker surely hadn't been keeping track of the chemical reaction of cookie formation mole for mole, but he had his domain too - boy, the cookies sure were delicious!

"But you won't know Chemistry by knowing how to bake, would you? That's UV completion!" - The smile on Naomi's face vanished momentarily, *"The Higgs is sick, Mijo!".* She shed a fake tear.

The particle zoo wasn't the most transparent place at the moment. Physics at low energy fails to explain physics at higher energies - alas, the poor baker knew not how chemistry worked. Sugar, spice and 'everything nice' combines with chemical X to create the powerpuff girls, but why? Of course, chemistry! Professor Utonium knew about things called electrons, and protons and how their commotion conspired to make the perfect little girls (or cookies!). These 'high-energy' things have always existed harmoniously with our ability to predictably explain - beta decay needed explaining so we had to bring in the W bosons and the Z - that caused its own problems and the Higgs needed to come forth to the rescue. Now the Higgs is being a crybaby and not eating enough. A baby must eat but the Higgs mass is just too low for the current understanding to be supreme!

"Haha! We'll invent some higher energy particles, and pray, pray and pray that those will be real too, just like the W and the Z and the Higgs! Now, let's enjoy the party. Merry Christmas, Naomi!" - It was true - particle theory was a lot of inventing. You don't discover, you cook up particles and based on some rules, write models (like the Standard model) with them! And once you're down to models, it's a lot of God-work sans God-powers.

"Haha! The Demographic Principle", we say together. *"Anything is allowed in physics unless explicitly forbidden!"*

Naomi's smile had been restored, now with one closer to home. This year, the Christmas party at the department promised to be something - although, excited physicists had mostly gathered for the food, and the wine - Craig the department administrator was conducting the Bingo game by the huge spread. It was a great deal because the theorists and the experimenters were together for once, meeting over eggnog and turkey. Conversation everywhere!

-*"Hola! Did you eventually manage to cool the Rubidium down?"*

-*"The nanoKelvin thermometer I made works, but the Rubidium - meh! They told me in undergrad that everything in REAL labs would function like perfect. Now I'm in grad school in America and my oscilloscope trace goes bust fifteen times an hour! How's your pen and paper work?"*

-*"OMG! Is that really? Sigh! Well that's a bummer... Maybe hit the oscilloscope a bunch'a times? Thankfully I left all that ages ago. Told myself theory would be fine even if I wasn't a Math genius. Talking of math, I can't help feeling I'm the worst at it. But my paper comes out in a month, hopefully."*

That would be very typical dialogue in a roomful of "impostor" physicists. And wait, the Impostor syndrome also has a brother:

-*"Oh ya sure! You bad at math!? Not happening! Everyone feels that way. So don't YOU get perturbed! I'm the one who really sucks at all this! How ever in the world did I get admitted in here?"*

Below the decks in the basement lab, the nanoKelvin thermometers built from scratch and all the immense calculations performed with underestimated success would not ward Impostor's away. All these physicists are sharks of their undergrad pools transformed into fishlets in the graduate ocean.

-*"Perturbed! Huh! The whole problem is that things aren't all perturbative, isn't it?"*

Sometimes you could hope to solve problems by using solutions to classic problems like the harmonic oscillator and see if your real problem is just a *slight* modification of that. Yeah, maybe gently nudge your harmonic oscillator and you'll do fine to use perturbative solutions. Well, if you hit it with a sledgehammer, uh well, there goes your perturbativity. All is lost! Lol! The question now is - how slight is slight?

-*"Haha! I had a dream last night - I was working on this optical trapping issue and in the end I ended up with a linear second order differential equation with constant coefficients - a bit of variation of parameters and it worked out analytically, can you believe it? In closed form!"*

If this wasn't a joke, I don't know what was. Yeah, closed form is the dream. Pretty looking solutions are the dream. Frictionless pulleys and spherical cats are the dream. Analytically solvable Hamiltonians are paradise regained. Approximations are the instrument of regain - and the reason you can talk about atoms and molecules without worrying about whether the W boson messes up solid state physics!

Why I say so? Kinda long-winded explanation, but here goes: Using your God-like freedom you are free to theorize any number of particles you like, perform any number of calculations as you will... and then, you wait... till the experimenter tells you what the real numbers are. Actual numbers let you explain nature, not symbolic alphabets - because your model may have an infinitely expanded particle zoo with particles of arbitrary rest masses. You'll see some of those in your accelerator. Does it mean that the others are ruled out? Not necessarily! The energy of the collider might not be enough to produce them and so you just end up saying that these unseen particles have a much higher mass than the energy you are putting in (mass and energy are related, hail Einstein!)! Effects of heavy particles are multiplied by small numbers (how small is small!?), so they are ignored. If you actually see a new particle, you can measure its mass (*"Ahem! the neutrino"*)... Okay you can **in principle** measure its mass, and put it in your theory and calculate other things with it!(and also your ticket to Stockholm ! Promise!)

-*"Small things are bae!"*, that was the motto the day!

-*"Expand and Truncate! Expand and Truncate! - That's what physics is!"*. Okay, maybe **this** is the motto.

Expand the Dirac equation and you'll get back the Schrodinger equation. Expand out General Relativity and Special Relativity is like the 'constant term' of the Taylor series. Unfortunately, we are back to the baker and his lack of knowledge of chemistry again. If you know the high energy theory you need only 'integrate out' things to get back the low energy stuff - integrate out atoms and molecules and treat cars to be like point particles - Newton's laws will work! Work quite well, actually. Regardless of all the Quantum voodoo going on deep beyond the realm of the microscope, this process, called 'renormalization', makes sure that the engineer never has to bother about the theory of everything!

"*Oh, I don't really think a theory of everything should exist. There will always be a higher energy scale that lower energy beings will not perceive, and engineers at the lower energy still don't need to bother about it!*", Manki was around. "*And oh, I do hope you are expanding and truncating in a small dimensionless parameter!"*. His voice was giving off very ominous portents.

Only dimensionless things can be compared and can be called small or large - the small nudge to the oscillator can be called small only with respect to some appropriate scale - in this case the ratio

$$\frac{\text{energy imparted by nudge}}{\text{energy of my harmonic oscillator}}$$

is dimensionless, and can be compared to numbers. If the ratio is very small compared to 1, then, sure it's small.

And yes, if you expand and truncate in a large parameter, you might as well say (quite incorrectly of course):

$$\frac{1}{1-5} \approx \underbrace{1+5+25+\ldots}_{\text{expand!!}} \approx \underbrace{1+5}_{\text{truncate!!}} = 6$$

That is usually what happens if you use perturbation theory to solve the oscillator hit by a sledgehammer. Or if you try to solve Quantum chromodynamics using Feynman diagrams. Getting to know if something is small is not really a small problem!

Anyway, theories are just that - theories, fun (sometimes!) to make and believe. And to the theorist, always make-believe. In the end it's the demographic principle - in the end there are no laws, anything that may happen, can happen. With a certain probability of course.

Only the experimenter can make a difference - That's a theorist's two cents anyway. NO!- say the experimenters. Our lives without you would be a lot of soldering and painting and connecting wires with no idea what to look for, and what to look at. We are thankful that you exist!

Awww!!!

Enough science talk, let's get back to the Christmas party : There was Andre, in a Santa hat, giving off his tired "It's-not-holiday-season-it's-recommendation-letter-season" face, occasionally thanking people on their *"Hey Andre, thanks for the awesome lectures on RG flows!"* His TA was away on purpose, lest he start asking about the undergrads in a bid to find content for his rec letters. Saul had just won the Nobel Prize, and he was busily filling his plate with sushi - his speech was good, but not as great as the skit he acted in. It was a skit where he played Snow White and his seven students played the dwarves - only this Snow White had eaten the apple that fell on Newton's head. She fell into a coma immediately. The experimenters' gingerbread house was standing strong and sturdy. The theorists' one had fallen over due to lack of dexterity. "*BINGO, BINGO, BINGO"*, cried Craig from the other end of the room as more desperate physicists lined up to play Bingo for the most attractive prizes - more free food!

The undergrads had snuck up for free food too, and Michelle was with them, telling them about things very physics and very non-physics - particularly how real calculations that came up in solving real problems weren't really very elegant, one very undergrad misconception. Physics of course wasn't a very clean subject that always admitted beautiful solutions - the beauty was in the thrill of having found a solution! With seven assignments and labs a week, life as an undergrad wasn't the most stress free either. But hey, there are always Christmas parties right? "*Baby steps*", Michelle was saying. Because even the best of us feel that way.

That was very encouraging indeed, even for the grads. Michelle was the best. The biggest skill we had been asked to learn all these years was the skill to not give up - and it's a skill that doesn't come easy. Michelle was who the department looked up to.

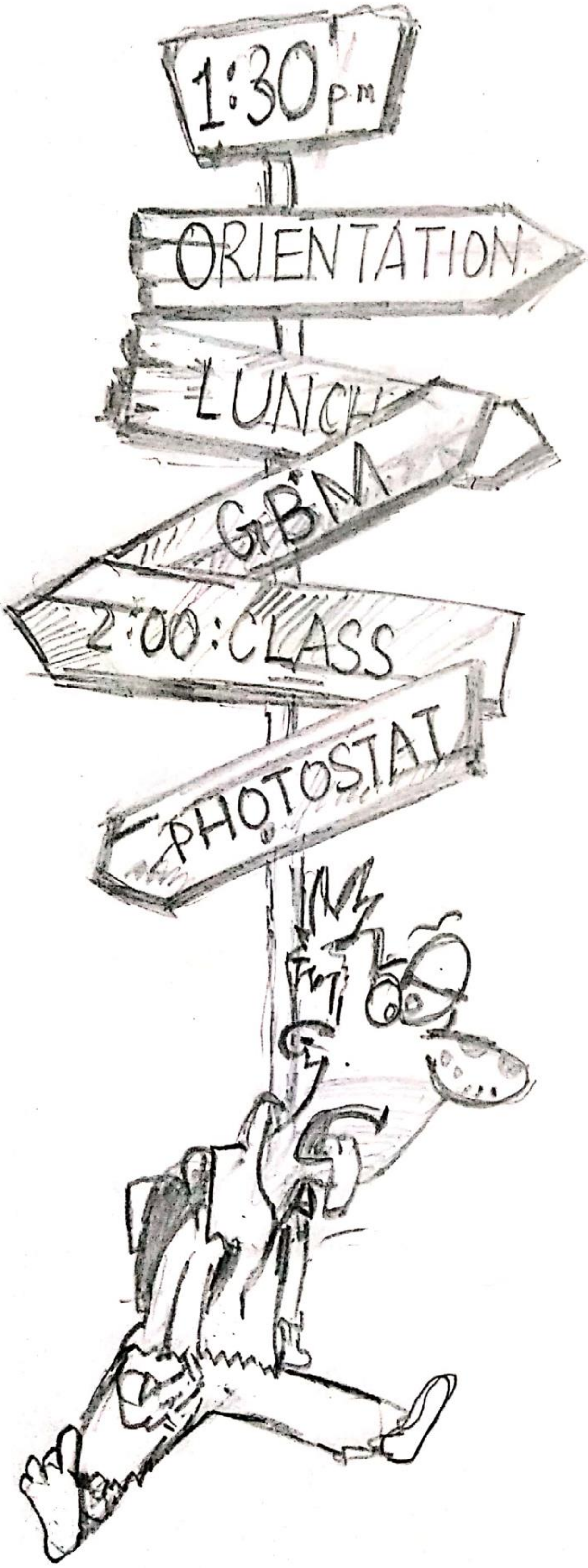
And so, there I am, taking a survey of the hall, clearly lacking a real reason to exist, writing stories about how nature works and hoping they come true.

-"*Oh, don't give me that look, Mijo. You know there is nothing else you'd rather do! Time for Photos though, woohoo!!*

The party was over. People were going to get back to their offices and labs - loads to do. But wait, phones out, photos first!

Nothing like some overworked yet grinny physicists coming together for a very festive department photo.

HOW TO BREAK THE BREAK



Mahak Sadhwani

THE LIFE BEYOND

#3YearPhysicsChallenge

-ZACHARIAH JACOB

For the uninitiated, the latest viral trend on social media is the #10YearChallenge where one posts a photo from ten years back after splicing it with a contemporary snap to showcase the contrast and the progress one has made over the last decade. Being an entrepreneur who did Physics in College and later Law as well, when I was called to contribute an article for *Echo* on my 'success' story which I believe is a very subjective term, I was initially a bit sceptical wondering whether mine is yet a case study fit for such an exercise. After pondering for a while, I did feel a sense of vindication over my career choices which have been anything but conventional, to say the least. To provide more context, I too shall take the much-hyped social media plunge here and go back in time because even though I am unsure about the success part, at least there is a story to narrate which I am now glad to realise, is perhaps relatable.

It was in the year 2006 that I joined St Stephen's College as an undergraduate in Physics. Unlike it was for some of my classmates, my decision to join Physics happened by pure chance. My late mother who I was very close to wanted me to become a doctor because she believed I could find some sort of a panacea for her heart ailment which she was suffering from a very young age and finally succumbed to six years back. My father too liked the idea because coming from a business background, he thought it will be an effective way to partly mitigate the cost of the ever-increasing medical bills!

However, as destiny would have it, even though I cleared the entrance examination, I could not make it to the final list of Christian Medical College, Vellore as I had failed the mandatory Bible test. Drawn between the option of taking a year off in some remote corner of Kerala for entrance coaching and coming to Delhi with my fellow comrade, schoolmate and now business partner - Thomas Fenn, who was then supremely focussed to become a Physicist and subsequently join the NASA (but ended up switching to a more comfortable Economics after the first year itself!), it was an easy choice for me. I too opted to join Physics as it was considered a respectable course to do for anyone from a science background.

For me, the journey from the interview room to the ‘Grad-D’ has been the most enlightening and fascinating one I have ever undertaken. The transition from school to college, however, was not smooth. Coming from a remarkably conservative boarding school atmosphere, the freedom resident life in college offered was overwhelming and it did not take me much time to get carried away. While we had several stalwarts among our faculty whom I have always looked up to for their persistent passion and the unique pedagogies which definitely inspired many of my classmates to thrive in the field of academia or research, I did not imbibe much academically and started losing focus. My sole motto, on the contrary, was to ensure I managed to pass and complete the course without giving up, which I now really regret especially after my newfound interest in the subject after reading Stephen Hawking's *Brief Answers to the Big Questions*.

Notwithstanding my diminishing interest in academics, I soon learnt there is more to education than the four walls of the classroom. The life in college offered me many an opportunity to develop a fair understanding of social, political and economic issues around and open up my world to endless possibilities which were earlier alien to me. I still cherish the long conversations and debates on existential and metaphysical questions with some of my peers who are still my closest friends. Though I knew that understanding and solving piquant real-life problems satisfied me more than learning the intricacies of abstract theory, I was clueless as to what my future might entail.

By the end of the third year, even though I managed to survive the battle, I was merely mediocre at best –a dazed and confused student bordering between teenage and young adult life crisis. The only thing I knew for sure was Physics was not for me. However, the silver lining was by now I had managed to set the bar so low, I could feel the weight of parental and societal expectations slowly slide away. I could choose what I wanted to do as long as it still continues being respectable!

Even though pursuing law was not my most preferred choice, in the end, it became the only choice I had after college as the prospect of finding a decent job was bleak thanks to the 2008 global financial meltdown and I was not yet ready to go back home! Having secured admission in Campus Law Centre, Delhi University, I decided to give it a genuine shot. The analytical approach and the problem-solving skills that I learnt in Physics came in very handy and I began enjoying what I was studying with an extra conviction to redeem myself when life was giving me a second chance. Fast forward to 2012, I was much more grounded than before having decently excelled in both academics and co-curricular activities and I ended up being one of the first students in my batch to get a campus placement, that too with a reasonably cushy offer.

Naturally, I took up the job and worked there for almost three years. Even though I was having a decent progression, somewhere deep inside, there was this niggling feeling that made me realise I am not yet ready to settle down in life after having explored just one career path. This constant itch prompted me to step out of my comfort zone and break the monotony.

Coincidentally, my partner Thomas was also going through a similar phase and during one of our catching up sessions, we had an epiphany to revisit this wild idea we had in college to start a 'mallu-dhaba' outside the college, in case we ever had to drop out! United by our mutual admiration for Kerala cuisine and by then having had figured out that there is a clear imbalance in demand-supply for such a concept in Delhi, we saw this potential to turn our college backup plan into a full-fledged business.

However, opening a restaurant business in Delhi with no prior experience was not a cakewalk and it took a big leap of faith for us. My grandmother did not think this was a respectable venture for a lawyer to undertake and she was worried that my prospects in the marital market will be adversely impacted! Despite the genuine concerns, we followed our guts and Mahabelly was finally opened on 25 March 2015 by none other than the eminent Stephanian and Parliamentarian - Dr Shashi Tharoor. Being thrown in the deep end, the struggle was real and we had to put in everything we had learnt inside and outside classrooms to keep ourselves going till we finally started seeing some hope after about six months. From waiting tables to helping in the housekeeping, we did learn a lot on the job and started appreciating virtues likes patience and empathy much more.

In hindsight, while my experience in college set me free from the burden of living up to someone else's expectations and doing things at my terms, the decision to quit my secure job and venture into an unchartered territory helped in self-actualization and enabled me to be in the driving seat of my life in this mad rat race we are all unwittingly part of.

Once the restaurant operations had settled and our bottom-line became healthy, with the liberty and financial freedom that the entrepreneurship life offered, I also co-founded a law firm called Actus Legal, to keep the lawyer in me busy as well. Recently, my wife (yes I did manage to find a beautiful partner!) and I opened another Indo-Arabic restaurant called Game of Grills in Gurgaon, Haryana to diversify our portfolio.

I have also had my fair share of failures as well with two restaurants that we had opened shutting down in less than a year’s time. While I did burn my fingers, the setbacks were a learning curving to discover my strengths and weaknesses and take on more challenges.

I still do not know if I have found my true calling or whether this is any success story. But what I do know for sure is that, for me, success is being able to create a meaningful, purposeful and fulfilling life for oneself and learning how to use that to make an impact and difference to the lives of others. This is what the student in me is striving for, every single day.

Random sampling, sample transformations and integration

Abhishek Chakraborty

A common problem that plagues physics undergraduates at St. Stephen's college is what might be called the Saturday night problem. After a long week of classes and (way too many) labs, you might want to relax but are unsure of how exactly you should do so. Perhaps you're struggling between ordering in and watching a movie and going out to dinner with friends. For statisticians, the humble unbiased coin comes to the rescue. It allows you to choose from two equiprobable outcomes and thus your dilemma is resolved.

But suppose you're a particularly indecisive person. Maybe you're struggling to choose from eight potential methods of relaxation. This time you take out three unbiased coins. You toss them sequentially and write down, for each, a 1 if you get heads and a 0 for tails. In the end, you put these three numbers together to get a 3-bit binary string. If we number the eight activities 0 through 7, we can convert the binary string to decimal and thus you've randomly chosen how you want to relax.

The above discussion might seem like an obtuse example, but our attempts had a singular goal: To find a way to sample uniform probability distributions. We've successfully made a random number generator that generates integers from 0 to 7. It's easy to see that if we had more options to choose from, we'd simply use more coins. To be exact, if we want to choose from 2^n outcomes[1], all with the same probability, we would use n coins. Let us call this mechanism `randint(n)`. `randint(n)` can sample a uniform distribution of 2^n outcomes, labelled $0,1,\ldots,(2^n-1)$. An important thing to note is that this distribution is discrete.

But suppose you want to sample a continuous distribution of real numbers between 0 and 1. It might be useful to note here that what we call continuous is limited by the amount of precision we can handle. For certain use-cases, a discrete distribution seems continuous if two adjacent outcomes differ by the order of the maximum allowed precision. Consider a function `rand()` constructed as follows.

$$\texttt{rand()} = \frac{1}{2^n}\texttt{randint(n)}$$

Clearly, `rand()` will generate numbers in the required interval of [0,1) with two adjacent outcomes differing by $1/2^n$. For $n = 20$, this is only a difference in the sixth decimal place. Henceforth, we will treat `rand()` as an ideal continuous random number generator with outcomes in the interval $[0,1)$.

One usually comes across a similar `rand()` function in several programming languages like C++. And sometimes, `rand()` is the only random number generator a language offers by default. Thus, it is natural to wonder if we can sample random numbers from an arbitrary (read as non-uniform) probability distribution using only `rand()`. Since all outcomes of `rand()` are equiprobable, we can partition the sample space in a way to realize the desired probability distribution. Suppose we want to simulate a biased coin which turns up heads three times out of four. We can implement this by imagining a map from all outcomes $[0,0.75)$ to the outcome heads and the outcomes $[0.75,1)$ to the outcome tails. Naturally, the numbers corresponding to heads are now thrice as likely as those for tails, simply because there's thrice as many of them. This can be easily generalized to the case of continuous distributions. Let's look at the specific case of the exponential distribution.[2]

It is important to note that the intervals being sampled are inherently different. `rand()` samples $[0,1)$ while an exponential distribution samples values in the interval $[0,\infty)$. Consider an infinitesimal chunk of the interval $[0,1)$ denoted by $d\Upsilon$. We want to map this to an appropriately (exponentially) weighted interval in the target sample space denoted by dx. Without loss of generality, consider the following relation:

$$d\Upsilon = ce^{-\lambda x}dx$$

---

[1] The choice of 2^n might seem arbitrary here, but it is simple to imagine. If our number isn't a power of 2, simply consider the nearest power of 2 greater than the desired number and reject all binary strings corresponding to the numbers greater than the required number. The distribution is still uniform.

[2] Exponential distributions are ubiquitous. The sizes of aerosol particles in air are exponentially distributed. The time between two disintegrations for a radioactive sample follows an exponential distribution. And much more.

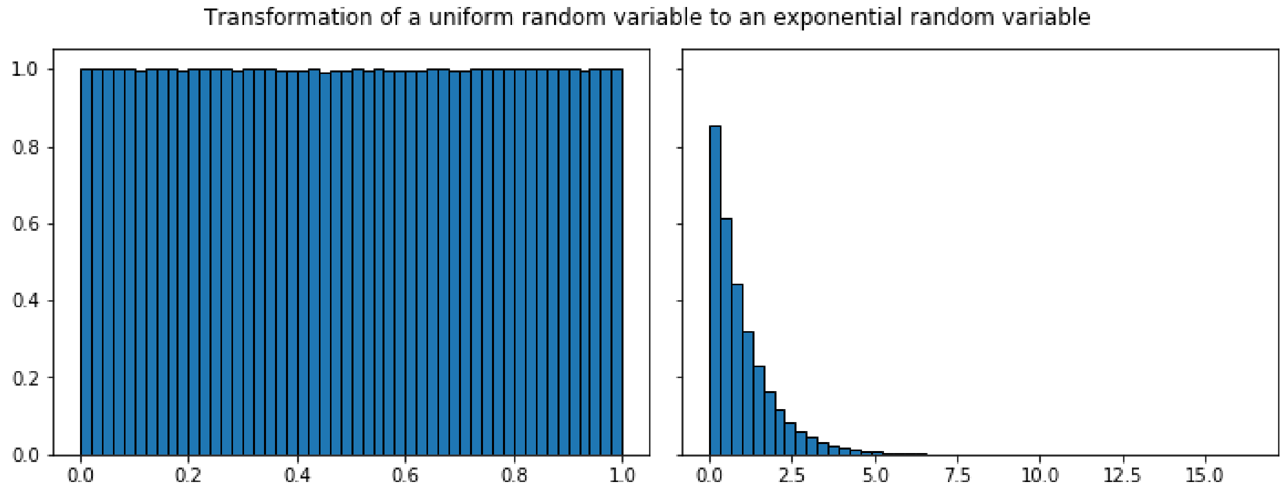


Figure 1 Transformation of a uniform random variable into an exponential random variable. The above figure was generated using 10 million generated numbers. You might be bothered by how empty the plot on the right looks, but consider that the horizontal axis is scaled differently in the two plots. Also refer to footnote 3.

Integrating this gives us a concrete relation between Υ and x.

$$\Upsilon = c'e^{-\lambda x} + c''$$

We must also relate the boundaries of the two intervals.[3]

$$\Upsilon = 0 \rightarrow x = \infty$$

$$\Upsilon = 1 \rightarrow x = 0$$

This gives us the following relation

$$\Upsilon = e^{-\lambda x}$$

which can be inverted to get

$$x = -\frac{1}{\lambda}\log \Upsilon$$

So, if we can generate a random sample using `rand()`, we can transform it into a sample x from an exponential distribution. This is the essence of sample transformation and allows us to sample, in principle, any distribution.

Note that we performed an integration in the procedure above to perform a sample transformation. This begs us to question whether integration and sampling are connected. Indeed, they are somewhat equivalent and often sampling is easier than performing an integration. As an illustrative example, let us consider a problem usually found in the first-year computational physics lab. The problem involves (uniformly) choosing random points in a square with an inscribed unit circle. The fraction of points that land inside the circle should be proportional to the ratio of areas which, in this case, is $\pi/4$. Let's try to see how precise a value of π we can obtain from this method.

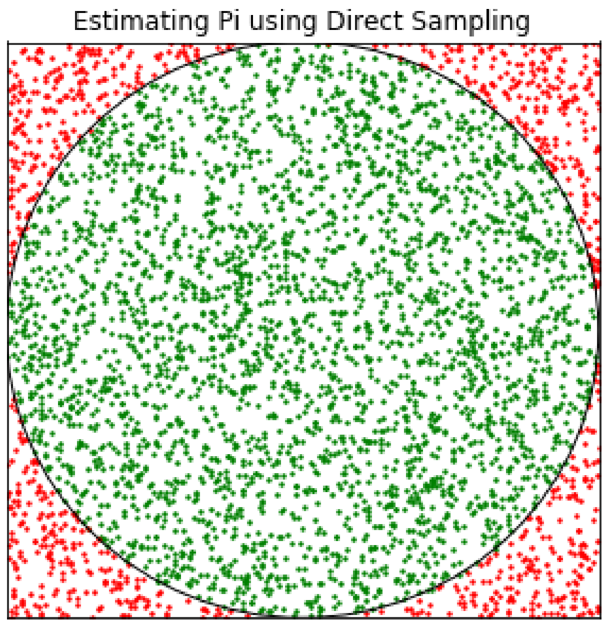


Figure 2 Calculation of π using direct sampling. The figure above was generated using 4000 points.

This problem can be reformulated as a series of Bernoulli trials, with the probability of 'success' being proportional to the ratio of areas i.e. $\pi/4$. Formally,

$$\phi \in \{0,1\}$$

$$P(1) = \pi/4, P(0) = 1 - P(1)$$

with and. It is obvious that the average value of ϕ is $\pi/4$. This might seem deceiving but we must remember that the experimentally calculated average value will agree with this in the limit of infinite trials. The average value of ϕ we obtain for

[3] This choice of the boundary relations might seem arbitrary, but this gives us much mathematical simplification.

an actual experiment of n trials has a distribution centered around the true mean value and a variance given by the following expression:

$$Var(\phi) = \frac{P(0) \cdot P(1)}{N} = \frac{\frac{\pi}{4}\left(1 - \frac{\pi}{4}\right)}{N}$$

This tells us that the more trials we use to estimate π, the more precise our value is. The standard deviation is the square root of the variance and hence

$$\sigma_\phi = \sqrt{Var(\phi)} \propto 1/\sqrt{N}$$

As an example, using a million points to calculate π gives a precision of two places of decimal[4].

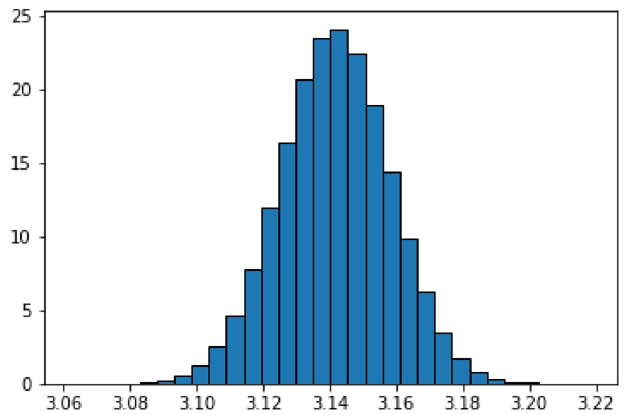


Figure 3 The distribution of the values of π generated using a million points each. The above distribution has a mean of 3.14 and a standard deviation of 0.02.

Here a parallel may be drawn to the act of numerically integrating the area, where the precision of the calculated value depends on the size of the infinitesimal area we consider. Integration is often more cumbersome and difficult, especially in higher dimensions. Thus, sampling is an effective method[5] in calculations that involve computing integrals.

Appendix: Real Random numbers

It should be noted that the random number generators (RNG) available in programming languages today are actually pseudorandom number generators. This means that they generate sequences of numbers which have very little correlations between terms in the sequence. There are various algorithms which have been tested over the decades and can be used for whatever simulations we may use.

However, given that quantum mechanics is apparently random to boot, we can try constructing actual quantum RNGs. A Stern-Gerlach device is a very good candidate for this. Consider a beam of electrons from a source like a heated filament, passed through an electric field and a collimator before being subjected to an in-homogenous magnetic field. The beam splits into two, one for electrons with spin 'up' and spin 'down'. This is the essence of the Stern-Gerlach experiment. If our source can be made weak enough to emit single electrons at a constant rate, it will go to either of the two beams. If we label the two states as 0 and 1 respectively and we can use this as our random bit generator. See (Feynman, Leighton, & Sands, 1964) for a thorough discussion of the Stern-Gerlach experiment.

References

Feller, W. (1968). *An Introduction to Probability Theory and Its Applications Vol I & II.* Wiley.

Feynman, R., Leighton, R. B., & Sands, M. (1964). *The Feynman Lectures on Physics Vol. III (Quantum Mechanics).* Addison–Wesley.

Krauth, W. (2006). *Statistical Mechanics: Algorithms and Computations.* Oxford University Press.

[4] The value of π is obtained by multiplying the mean of the area fraction by 4. The standard deviation also gets four times larger. Hence, we have two decimal places of precision instead of the expected three.

[5] Direct sampling, which is what we have discussed in this article, is also often difficult for higher dimensionalities when the entire probability distribution is hard to sample. However, methods like Monte Carlo sampling offer a way out and are used is various areas of physics. Refer to (Krauth, 2006)

The Moon Illusion

28th December 2018

Recently during one of my 'Night sky Photography sessions', I came across a rather interesting phenomenon. It's something we've all observed and like me, I suppose, given little thought about. Here it goes:

The moon looks far bigger (by about 50-75%) at the Horizon than it does at zenith

Not surprised? Well, you should be because this is actually not true! This apparent magnification of the moon at the horizon is called the Moon Illusion. Since forever I always thought there must be some 'Physics' behind the observation that I haven't bothered looking up and so on the fine day of 28th December 2018, I decided to find out. At this point I should mention that what I'm about to write is purely based on articles found via Google search, so don't believe everything (or anything?) I've written here.

There's a simple way to verify that what you observe is a mere illusion. Take a piece of paper, roll it to a size that seems to exactly block the horizon moon when held at one arm distance. Now take the same piece of paper, and use it to cover the moon at the zenith, it also covers the moon 'exactly'. The moon always subtends an angle of 0.5°! Another way to verify this is to take a multiple exposure picture of the moon as it rises from the Horizon and you'll see that the size does not change. So what is going on? Does the camera see one thing and we another? Before we answer this question let us rule out some of the 'explanations' that have been given:

1. Back in the 4th century B.C., Aristotle attributed this to atmospheric magnification, but we know this is not true, because if it was then the camera would have captured it. Another fact is that atmospheric effects would, in fact, make the moon appear smaller [1]
2. Eccentricity of the moon's orbit: This is trivially not the cause as the timescale over which we observe the moon illusion is a few hours, as compared to a few days which is required for this effect to manifest.
3. The moon observed at Horizon is about 2% smaller than at zenith due to a greater distance of the moon from the observer at Horizon than at zenith. This effect is rather small and in fact opposite to the Moon Illusion.

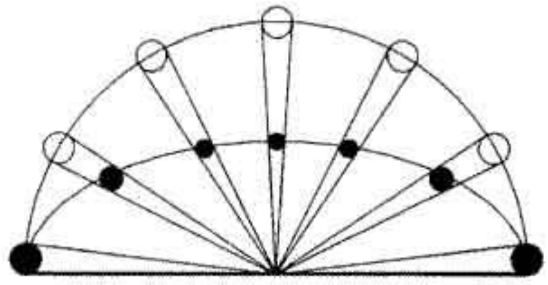
So I think we can establish that there is no 'Physical' explanation for what's happening, well because it's not happening at all! It's a mere illusion caused by the way our brain perceives distances. A few hypotheses that have done the rounds, but none established are stated as follows:

1. Ponzo Illusion: How we perceive the Moon's size has to do with how far away we think it is based on what's around it. Most of us see the top Moon, seemingly located in the distance based upon the convergence of the railroad tracks, as larger than the bottom Moon. Yet they're identical. This is known as the Ponzo illusion, discovered by Italian psychologist Mario Ponzo in 1913. In a real moonrise, it's thought that distant trees, buildings and landscape features play the role of converging lines.[2] However, this does not offer a satisfactory explanation, as then the horizon moon should appear both larger and 'father' than the zenith moon. But most people report the horizon moon to appear 'closer'. Secondly, this cannot account for the apparent 50-75% increase in size.
2. Apparent Sky dome: This is the most common explanation seen in 'textbooks'. This model assumes that we have a distorted perception of the sky and that it actually like an inverted soup-bowl, instead of a hemisphere. According to this model, the moon and any other object we

[1] See https://www.lockhaven.edu/~dsimanek/3d/moonillu.htm

[2] See https://www.skyandtelescope.com/observing/moon-illusion-confusion11252015/

see are projected images onto this flattened dome



Why should the brain create such a mental picture? It is suggested that (1) The mechanism is hard-wired into our brains from birth. (2) The mechanism is built up through experience, by daylight sensory experiences, from a host of visual cues in everyday life.
But there is the same problem associated with this theory as the previous one; the horizon moon should then appear 'farther' than the zenith moon. Secondly, many claim this picture to be highly misleading. Carefully notice that the sky dome diagram specifies that, for the person at the centre, all the Horizon and zenith moons on the hemispherical dome have the *same angular size* as the Horizon and zenith moons on the flattened one. [3] That is, what the person at the centre is seeing is not being shown to us readers by the different sized circles in the sky dome drawing, this is just the 'side-view' which is *not* what the observer sees.

These are the two main theories used to describe this illusion but hardly provide any convincing arguments. There are a few more theories such as the anisotropic visual space theory and Ebbinghaus illusion, but no single theory has emerged victorious. In September 2002, Ross and Plug published their book, "The Mystery of the Moon Illusion" (Ross & Plug, 2002). Some sites claim that it currently is the most complete source of information about the illusion (I personally haven't read this book yet). Apparently on page 195, they state: "The moon illusion is one of the few perceptual phenomena that tap a broad spectrum of sciences: astronomy, optics, physics, physiology, psychology, and philosophy. Its explanation illustrates the history of scientific explanation, and in particular the history of perceptual psychology."[4]

In my attempt to write this article I came across a number of websites, a few that accept these models with some hesitation and some that completely disregard them as 'misleading'. Therefore, in conclusion, I again urge you to not completely believe this article, it is simply to share my fascination with this illusion, which I believe most of us were otherwise oblivious of.

The horizon moon I took a picture of thinking I'll get better clarity as it appeared 'larger'

Priyanka Iyer

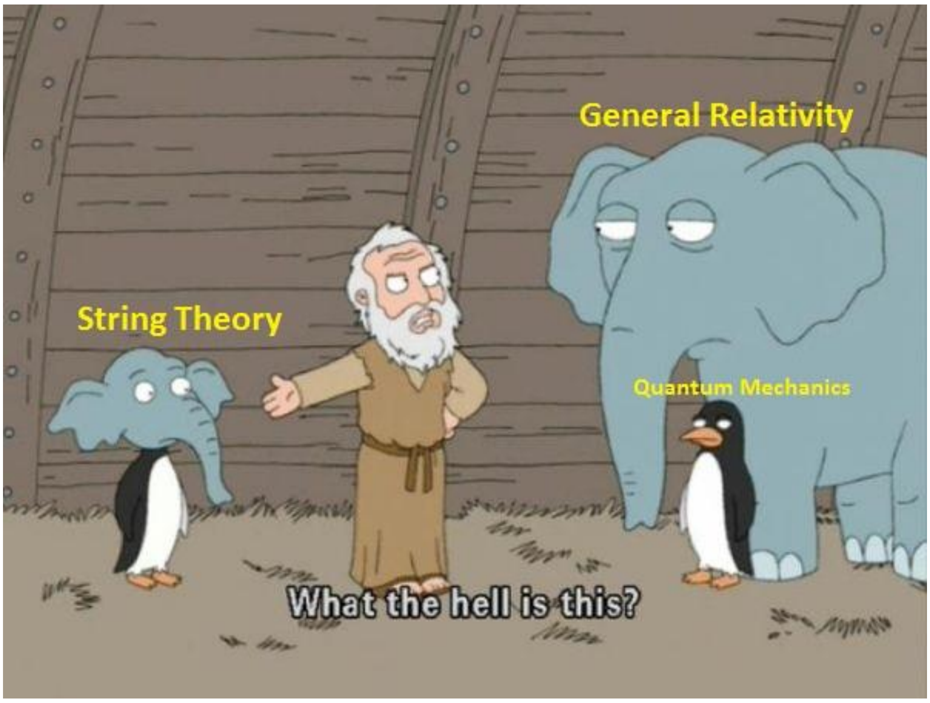
3rd Physics

[3] See https://lecerveau.mcgill.ca/flash/capsules/articles_pdf/moon_illusion.pdf

[4] See https://lecerveau.mcgill.ca/flash/capsules/articles_pdf/moon_illusion.pdf

CHILL SCENES

Rudra Kalra



Anonymous

A BOHMIAN RHAPSODY

- **Mrittunjoy Guha Majumdar**

Fluid droplets can bounce when placed onto the surface of a vibrating fluidic bath! Bizarre as that sounds, a student working in *Laboratoire Matière et Systèmes Complexes* at the *Centre national de la recherche scientifique (CNRS)* in Paris found this to be the case by using oil droplets and an oil bath, in 2005 [1]. If that was not bizarre enough, what if one were to posit that nature fundamentally is like that, at the quantum level? What if such pilot-waves are what could explain the peculiar (and fairly counter-intuitive) behaviour of particles in the realm of the microscopic, the *quantum*, as we know it? In the early twentieth century, it was discovered that the laws of Physics that govern macroscopic objects are not as effective in such small realms. For instance, in these realms, the act of observing physical phenomena actually influences the phenomena taking place [2]. In these realms, waves can act like particles and particles can act like waves [3, 4]. Matter can also go, rather 'tunnel' through, from one spot to another without moving through the intervening space. If that were not enough, information can move instantly across vast distances instantaneously in what Einstein best described as 'spooky action at a distance' [5]. Outlandish!

For most of the past century, the predominant explanation for the conundrum about why a particle sometimes behaves like a wave in the quantum realm has been what is called the `Copenhagen interpretation', which states that, in a way, a single particle really is a wave that is smeared out across the universe, and that collapses into a certain position only when observed. In a more generalized form, one can say that a quantum entity, say a particle, always is in a superposition of states, with regards to a property, till one observes it in just one of the many that are in the superposition. This *collapse* is found to be probabilistic in nature. However, what if one seeks to explain it deterministically? Enter: Louis De-Broglie and David Bohm, and their alternative interpretation, known as the `pilot-wave theory' [6], which posits that quantum particles are borne along on pilot-waves, similar to the one found at CNRS! Unlike other interpretations of Quantum Mechanics, such as the Copenhagen Interpretation or Many-Worlds Theories, the Bohmian interpretation (which, in fact, precedes the Copenhagen Interpretation) does not consider observers or the act of observation as primary and important for the predictions of Quantum Mechanics to hold true. It is a `quantum theory without observers', if you will.

In the Bohmian formulation, an individual quantum system is formed by a point particle and a guiding wave. In Bohmian mechanics, the wave function of a particle does not provide a complete description or representation of a quantum system. A wave function, in quantum mechanics, is a variable quantity that mathematically describes the wave characteristics of a particle. As per the Bohmian formalism, quantum mechanics is fundamentally about the behaviour of particles. These particles are described by their positions, and Bohmian mechanics discusses how these change with time. In this sense, for Bohmian mechanics the particles are primary while the wave function is secondary. For Bohmian mechanics the state of a system of N particles is described by its wave function $\psi = \psi(q_1, \ldots, q_N) = \psi(q)$, a complex function on the space of possible configurations q of the system, together with its actual configuration Q defined by the actual positions $Q_1, \ldots, Q_N$ of its particles. The theory is then defined by two evolution equations:

1. *Schrödinger's Equation* [7] defines the evolution of the wavefunction

   $$i\hbar \frac{\partial \psi}{\partial t} = H\psi$$

   for $\psi(t)$, where H is a nonrelativistic Hamiltonian, containing the masses of the particles and a potential energy term.
2. A first-order *Guiding Equation* defines the evolution of the positions of the particles

   $$\frac{dQ_k}{dt} = \frac{\hbar}{m_k} Im \frac{\psi^* \partial_k \psi}{\psi^* \psi}(Q_1, \ldots, Q_N)$$

   where $Im[z]$ denotes the imaginary part of a complex number z. Here $\hbar = \frac{h}{2\pi}$ where h is the Planck's constant, m_k is the mass of the k-th particle, and

   $$\partial_k = (\frac{\partial}{\partial x_k}, \frac{\partial}{\partial y_k}, \frac{\partial}{\partial z_k})$$

   is the gradient with respect to the generic coordinates $q_k = (x_k, y_k, z_k)$ of the k^{th} particle.

Researchers who have spent some time analysing the ideas of Bohm Mechanics with the appropriate scientific rigor accept that there can hardly be any scientific argument against this formalism. After all, Bohmian mechanics agrees with most, if not all, experiments in the quantum realm carried out up to now. Some of the best proofs of Bohmian Mechanics have arisen from studying the characteristics of the particle and its guiding pilot-wave, and relating them with empirical evidence.

Bohmian Mechanics is a Hidden-Variable theory. Hidden-variable theories are those that regard the Universe as inherently deterministic and only seemingly probabilistic due to certain variables that we are not aware of; certain variables that are *hidden*. In the case of Bohmian mechanics, it is the positions of the particles that are the hidden variables. Since Hidden-Variable dynamics are, by definition, *deterministic*, Wiseman [8] stated that the velocity-field of the hidden variable should be naively observable, which means it can be defined operationally as a *weak* value. These assumptions are found to be compatible with quantum mechanics only if the hidden variable chosen is the position of the particle, which is the case in Bohmian mechanics. You may ask whether such a 'weak measurement' of the velocity is actually a measurement of the velocity of the particle at all? Yes, it is, as has been recent shown by *Dürr et al* [9]. Weak measurements can also be used to observe the trajectories for particles, such as single photons [10].

Even though Bohmian mechanics has a certain resolution of the quantum wavefunction collapse and the measurement problem within the formalism, it has been plagued by its fair share of criticism. Most researchers of quantum physics also do believe that Bohmian mechanics is not a useful tool to do research. In the words of Nobel Laureate (Physics, 1979) Steven Weinberg, in a private exchange of letters with Sheldon Goldstein [11]: "*In any case, the basic reason for not paying attention to the Bohm approach is not some sort of ideological rigidity, but much simpler — it is just that we are all too busy with our own work to spend time on something that doesn't seem likely to help us make progress with our real problems*." Tomas Bohr, fluid physicist at the Technical University of Denmark and grandson of Nobel Laureate (Physics, 1922) Neils Bohr, recently gave a strong argument against Bohmian mechanics using a *gedanken* (thought) experiment [12]. Nonetheless, even with all its critics, Bohmian Mechanics is one of the most fascinating interpretations of quantum mechanics today. As unconventional as it is, it is one of the last hidden-variable theories that has survived the test of time. Maintaining the idea of nonlocality in the evolution of a particle has been what makes Bohmian Mechanics different from most local hidden-variable theories, and it is this that keeps de Broglie-Bohm's interpretation intriguing and relevant. As I like to say: harmonious, this Bohmian Rhapsody wafts along!

References:

[1] Couder, Yves, et al. "From bouncing to floating: noncoalescence of drops on a fluid bath." Physical review letters 94.17 (2005): 177801.

[2] Bohr, Niels. "The quantum postulate and the recent development of atomic theory." (1928): 580.

[3] de Broglie, Louis. "The wave nature of the electron." Nobel lecture 12 (1929): 244-256.

[4] de Broglie, Louis, and Rudolf Ernst Peierls. Einführung in die Wellenmechanik. Akademische Verlagsgesellschaft, 1929.

[5] Einstein, Albert, Boris Podolsky, and Nathan Rosen. "Can quantum-mechanical description of physical reality be considered complete?" Physical review 47.10 (1935): 777.

[6] *de Broglie, L. (1927).* "La mécanique ondulatoire et la structure atomique de la matière et du rayonnement". Journal de Physique et le Radium. *8 (5): 225–241*.

[7] Schrödinger, E. (1926). "An Undulatory Theory of the Mechanics of Atoms and Molecules" (PDF). Physical Review. 28 (6): 1049–1070.

[8] Wiseman, H. M. "Grounding Bohmian mechanics in weak values and bayesianism." New Journal of Physics 9.6 (2007): 165.

[9] Dürr, Detlef, Sheldon Goldstein, and Nino Zanghì, 2009, "On the Weak Measurement of Velocity in Bohmian Mechanics", *Journal of Statistical Physics*, 134(5): 1023–1032.

[10] Kocsis, Sacha, Boris Braverman, Sylvain Ravets, Martin J. Stevens, Richard P. Mirin, L. Krister Shalm, and Aephraim M. Steinberg, 2011, "Observing the Average Trajectories of Single Photons in a Two-Slit Interferometer", *Science*, 332: 1170–1173.

[11] Private exchange of letters between S. Goldstein and S. Weinberg; http://www.mathematik.uni-muenchen.de/ ~bohmmech/BohmHome/weingold.htm

[12] Andersen, Anders, et al. "Double-slit experiment with single wave-driven particles and its relation to quantum mechanics." Physical Review E 92.1 (2015): 013006.

AUTOMATED DETECTION OF CORONAL MASS EJECTIONS

Priyanka Iyer, St. Stephen's College

***Abstract*—The technique of the linear Hough transform has been previously used for the automated detection of CMEs in image sequences from LASCO [1] and later extended to STEREO COR-2 and Heliospheric Imager images. This can be used to provide a good estimate for the average velocity of the CME. The COR1 images are of great interest, as the height-time plots of these images show the CMEs in their phase of impulsive acceleration. We have developed an algorithm that can detect these CME features(seen as parabolas) from the height-time plots using the method of Hough Transform. The fitted parabola can be used to estimate the average acceleration of the CME in the COR1 field of view.**

The output of the algorithm is a list with properties such as the average acceleration, time of initiation and average velocity for each CME detected.

We start by explaining the transition from the method of the linear to the parabolic Hough transform. We then add a few notes on the various image processing and thresholding techniques used in the algorithm. This is followed by a comparison between the acceleration values determined by this algorithm and those manually calculated.

I. Linear Hough Transform

The technique of Hough Transform was originally introduced in 1962 and was used about a decade later in 1972 to detect lines and curves [2]. It is a powerful technique that can be used to detect any geometrical shape like lines, parabolas or circles as long as the parametric equation is known. Let us say we have an image in which we can locate all points (x_1, y_1) that may lie on a line. All lines passing through (x_1, y_1) are of the form $y_1 = mx_1 + c$. This in the (m, c) space represents a line of the form:

$$c = -x_1 m + y_1$$

Thus, each point (x_1, y_1) gets mapped to a line in the (m, c) space. Similarly, any two points P and Q will get mapped to two different lines in the (m, c) space. The intersection of these two lines will give the coordinates (m_1, c_1) that describes the line $y_1 = m_1 x + c$ that passes through the two points P and Q.

For n points in the x, y space(that lie on a single line), we will get n lines in the m, c space intersecting at a single point. Thus knowing the coordinates of this point of intersection, we can regenerate the line given line.

For implementing this technique, we use the polar representation $\rho = x\cos\theta + y\sin\theta$. Now each point x, y gets mapped to a curve in the ρ, θ space, instead of a line. This is done because the values of m and c are unbounded, but that of ρ and θ are not. We initiate a 2-D Accumulator array, with the various possible values of ρ and θ all having zero intensity.

Now for each x, y in the image, we vary θ and the corresponding ρ value is computed. This (ρ, θ) pair in the accumulator is incremented by 1. Once this is performed for all (x, y), it is easy to see that the (ρ_1, θ_1) pair in the Accumulator with the greatest value of intensity is the point of intersection and gives the coordinates for the line $y\sin\theta_1 = \rho_1 - x\cos\theta_1$. This method is very powerful and can be used very well to detect lines even in noisy images (Figure 2).

This technique has already been implemented to detect ridges in height-time maps of the LASCO C2/C3 data and has been used to make the automated CACTus catalogue. The slope of the detected lines gives us an estimate of the velocity of the CME([1]).

The CMEs in the inner corona accelerate and hence they appear as parabolas in the height-time plots of COR1. Therefore, detecting parabolas in these height-time plots can give us an estimate of the average acceleration of the CMEs in the inner corona. To do this, we first need to understand the parabolic Hough transform.

II. Parabolic Hough Transform

Let us say a point x', y' in the input image lies on a parabola of the form

$$(x' - x_1)^2 = 4a(y' - y_1)$$

. To obtain the family of all possible parabolas, we can add an additional θ coordinate to the above equation, that represents the rotation of the parabola by the angle θ about it's vertex. Here, the hough space will have 4 dimensions for x_1, y_1, a and θ. Thus, we would have a 4-D array for our accumulator.

However, implementing this would be computationally taxing. For each x', y', we would have to vary over all x_1, y_1, a to compute the corresponding θ and then increment the accumulator.

1) Assumptions: Our aim was to develop an algorithm for parabola detection in COR1 images. We, therefore, attempt to decrease the computational strain by reducing the 4-D accumulator to a 2-D one with certain physical assumptions regarding the problem.

a) Fixing θ: From Figure 3, we can see that the CMEs can be represented by parabolas with a fixed $\theta = 0^o$, with the physical significance that the CME is assumed to be accelerating in the inner corona and hence the COR1 field of view.

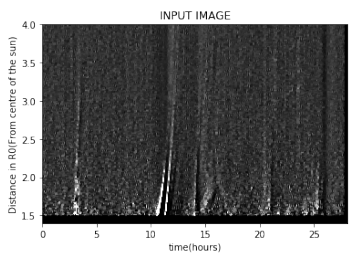


Figure 1: An example of a height-time plot

b) Fixing y_1: We can assume the CME to start with zero velocity from a height R_0 (surface of the Sun). This fixes our $y_1 = R_0$. We are now left with the equation:

$$(x' - x_1)^2 = 4a(y' - R_0) \tag{1}$$

For each x', y' we have to now find x_1 for each a, then increment the corresponding (x_1, a) pair in the accumulator.

2) Determining Acceleration: The parameter a is directly related to the acceleration of the CME. By applying dimensional analysis, a can be used to estimate the average acceleration. If we assume the CME to be a rigid body, with a constant acceleration then its position varies with time as:

$$y' = R_0 + \frac{Acc(x - x_0)^2}{2} \tag{2}$$

Where Acc is the acceleration of the CME and x_0 is the time of initiation.

Comparing equation 1 and 2 , it is easy to see that a and Acc are related as

$$Acc = \frac{1}{2a} \tag{3}$$

For any given image, we can set the natural length scale y_0 as the value of each pixel in terms of R_0, while the natural time scale x_0 would be the cadence value of the image. This gives us the following:

$$y = y_0\bar{y} \qquad x = x_0\bar{x} \qquad a = \frac{x_0^2}{y_0}\bar{a}$$

Where $\bar{y}, \bar{x}$ and $\bar{a}$ are dimensionless. Further, the numbers $\bar{x}$,$\bar{y}$ represent the pixels in the image. We can now treat the system in these dimensionless coordinates i.e. :

$$(\bar{x'} - \bar{x}_1)^2 = 4\bar{a}(\bar{y'} - \bar{y}_1) \tag{4}$$

Once we find $\bar{a}$ by applying the parabolic Hough transform, we can find acceleration by the following relation:

$$Acc = \frac{y_0}{2x_0^2\bar{a}} \tag{5}$$

3) Determining Average velocity: Once the parabola is detected, we fit a linear curve to the points lying on the parabola. The slope of this curve, gives us a measure of the average velocity of the CME.

III. The Dataset

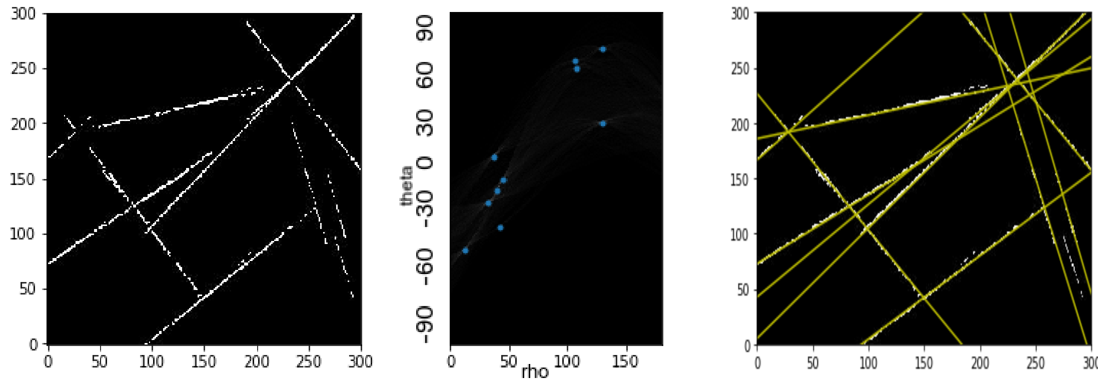
STEREO (Solar TErrestrial RElations Observatory) is the third mission in NASA's Solar Terrestrial Probes program (STP). It employs two nearly identical space-based observatories - one ahead of Earth in its orbit, the other trailing behind - to provide stereoscopic measurements to study the Sun and the nature of its CMEs. The STEREO spacecraft is comprised of four instruments: an extreme ultraviolet imager, two white-light coronagraphs and two heliospheric imagers[3]. The COR1(coronograph 1) telescopes each observe a range from 1.3 to 4 solar radii, while COR2((coronograph 2)telescopes observe from 2 to 15 solar radii. In this project, we have developed an algorithm for the COR1 images, as in its field of view the CME is in its acceleration phase.

The height-time plots and Hough space have been subjected to the following image processing techniques for better detection.

A. Median Filter

The very first filter applied to the height-time maps is the median filter. It is a non-linear filter which is very effective in removing salt and pepper noise, while preserving the CME features.

The filter works by moving through the image, pixel by pixel, replacing each value by the median of the



(a) Input Image (b) Hough Space (c) Detected Lines(yellow)

Figure 2: Example of multiple line detection by Hough Transform

neighbouring pixels. To do this, we have taken a kernel of size 3x3 pixels as the neighbourhood, and the centre pixel is replaced by the median of this neighbourhood. Since the median, unlike the mean, is less sensitive to extreme values(outliners), this method reduces noise without affecting the sharpness of the image[4].

B. Gamma Correction

Despite the application of the median filter, the ridges corresponding to the CMEs are not clearly visible due to the 'bleached' background. To make the ridges brighter and reduce background brightness, we apply gamma correction to the image. Note that this step is only to make the ridges more visible to the human eye, computationally it does not affect the Hough transform too much.

Gamma correction is described by the simple power-law expression [5]:

$$I_{out} = I_{in}^{\gamma} \tag{6}$$

For $\gamma < 1$ the image background gets brighter, while for $\gamma > 1$ the background gets darker.

C. Image Thresholding

The threshold value for identification of bright points (corresponding to the ridges) changes from image to image. Similarly, the threshold value for identification of bight regions(ideally points) in the Hough space also changes from image to image. To make this threshold compatible with different images we have used adaptive thresholding. Thus threshold value T changes from image to image and is given by the equation:

$$T = I_{mean} + C \times I_{\sigma} \tag{7}$$

Where C is a constant, I_{mean} is the mean and I_{σ} is the standard deviation of the intensity values of the input image.

The value of C in the algorithm was fixed by hit and trial, by selecting that value of C which gave maximum efficiency of CME detection.

D. Connected-Component Labelling

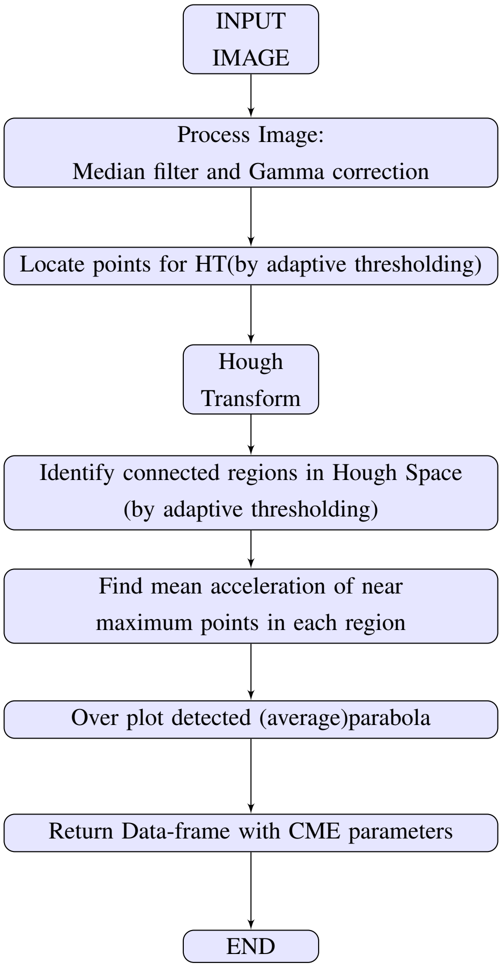
Since the ridges in the height-time plot are not properly defined, i.e. do not correspond to a single parabola, we do not get isolated peaks in the Hough space. Instead, we get regions with near maximum intensity values. Moreover, two different regions(corresponding to different CMEs) in the Hough space may show similar intensity values, making it hard to identify if they belong to the same CME or different ones. Therefore we first identify the connected components in the hough space through connected component labelling and then locate the near maximum values in each region.

In connected component labelling, we scan an image and group its pixels into components based on pixel connectivity, i.e. all pixels in a connected component share similar pixel intensity values. Once we identify these regions, each pixel given a colour based on the region it was identified in [6]. The threshold intensity above which the intensity values must be considered while identifying connected regions in the Hough space is also decided using the adaptive method discussed earlier.

Once these regions are identified, in each region we average the (x_1, a) pair corresponding the near maximum intensities, to get the average parabola that fits the identified ridge.

IV. Flowchart

The following flowchart broadly depicts the steps involved in the algorithm of the parabolic Hough transform:



V. Results Obtained from COR1 dataset

We have applied the technique of Hough transform for a number of images for different CMEs. Here we have shown the results obtained for a few CMEs which have been previously analyzed manually [7] and have compared the results. The images used are height time plots of the CME at different polar angles, representing different parts of the CME. Interestingly, different parts of the CME seem to show different acceleration.

Since the paper with which the results have been compared [7], find velocity and acceleration by numerical differentiation of the height-time plots, the error in acceleration is rather large. Therefore, a comparison of average velocity may be used as a test for studying the accuracy of the algorithm.

After the algorithm is applied to the images for a given day, we eliminate the parabolas corresponding to low-intensity points in the Hough space. This is done as the low-intensity points generally correspond to incorrect detection of parabolas in images with no observable CMEs. The average velocity is found by fitting a line to the points lying on the detected parabola.

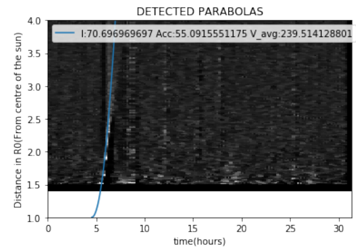


Figure 3: Detected Parabola in a Height-time plot CME on 13/02/2009

A. *CME on 13/02/2009*

The values of velocity from the numerical differentiation plots lie between $250 km/s$ to $500 km/s$ [7](including the error), while we get values ranging from $240 km/s$ to $320 km/s$(I) which lie more or less within the error range.

SNo.	Acc	Angle	Intensity	Std_A	V_{avg}	X-Coor
1	55	139.000000	70.696970	31	239	4.557080
2	87	127.500000	47.571429	42	301	4.914915
3	87	124.000000	146.361111	61	301	4.996394
4	97	147.000000	57.824561	102	318	5.018659
5	83	142.166667	58.574468	92	293	5.086693
6	97	120.833333	59.800000	119	318	5.094507

Table I: Values of acceleration(m/s^2) and velocity(km/s) for the CME on 13th Feb 2009

B. *CME on 08/05/2007*

For this CME the numerical differentiation gives values of velocity between $350 km/s$ and $600 km/s$[7](including error), while we get them between 310 km/s to $570 km/s$. Again, the average velocities lie mostly within the error range. Also, the CME corresponding to X-Coor=4.14 (see II)is not the same CME as the others. This is because X-Coor is a measure of start time.

SNo.	Acc	Angle	Intensity	Std_A	V_{avg}	X-Coor
1	55	135.166667	31.400000	13	240	4.148089
2	92	137.166667	81.480769	90	310	5.148946
3	107	129.500000	21.250000	96	334	5.241667
4	132	138.666667	51.608696	118	371	5.297108
5	270	132.000000	48.300000	96	530	5.537440
6	257	130.333333	56.692308	125	517	5.539349
7	315	135.166667	37.666667	48	574	5.556047

Table II: Values of acceleration(m/s^2) and velocity(km/s) for the CME on 8th May 2007

C. *Other CMEs analysed*

We have applied the algorithm to various CMEs and the results obtained have been tabulated below. For each CME, we report the maximum, minimum and median values of acceleration(m/s^2) and velocity(km/s), determined over all angles. The start time of the CME is taken as the median value of the base of the parabola, taken over all angles.

SNo.	Date	Time	Acc_{max}	Acc_{min}	Acc_{median}	V_{max}	V_{min}
1	03/03/2011	13:54	74	74	74	279	279
2	03/03/2011	16:46	118	64	118	442	352
3	03/03/2011	18:54	179	45	112	433	216
4	03/03/2011	20:39	58	58	58	246	246
5	13/04/2011	06:19	220	220	220	478	478
6	13/04/2011	15:27	23	11	14	155	108
7	13/04/2011	19:45	68	68	40	265	205
8	13/04/2011	20:28	475	387	431	704	634
9	13/04/2011	22:33	270	232	260	512	491
10	25/03/2008	01:19	64	64	64	259	259
11	25/03/2008	14:40	68	14	31	265	120
12	20/12/2008	20:10	232	119	139	491	352
13	13/05/2013	01:44	284	107	189	543	334
14	13/05/2013	07:31	284	284	284	543	543
15	13/05/2013	07:55	61	35	48	253	190
16	13/05/2013	15:34	315	102	146	574	326
17	22/11/2011	01:24	209	30	61	467	176
18	22/11/2011	05:18	139	58	79	381	246
19	22/11/2011	08:08	102	102	102	326	326
20	22/11/2011	20:37	162	28	81	410	172
21	22/11/2011	23:19	179	35	107	433	190
22	25/03/2008	14:46	68	6	51	265	82
23	26/04/2008	03:17	189	189	189	443	443
24	26/04/2008	13:55	220	220	220	477	477
25	26/04/2008	19:56	220	199	209	477	454

Acknowledgement

This work was supported by the National Initiative on Undergraduate Science(NIUS) undertaken by the Homi Bhabha Centre for Science and Education, Tata Institute of Fundamental Research(HBCSE-TIFR), Mumbai, India.

I would like to thank my supervisor, Prof. Dipankar Banerjee for giving me the opportunity to learn under him and for his constant guidance and support throughout the course of this project. I would also like to extend my gratitude to Dr Vaibhav Pant and Ritesh Patel, for their valuable inputs and extensive discussions that were instrumental in the completion of this project.

References

[1] D. Berghmans, B.H. Foing, and B. Fleck. Automated detection of cmes in lasco data. 2002. SOHO-11, From Solar Min to Max: Half a Solar Cycle with SOHO, 11-15 March 2002, Davos, Switzerland.A symposium dedicated to Roger M. Bonnet. Edited by A. Wilson.

[2] Richard O. Duda and Peter E. Hart. Use of the hough transformation to detect lines and curves in pictures. *Commun. ACM*, 15(1):11–15, January 1972.

[3] Stereo. https://stereo.gsfc.nasa.gov/img/mpb.pdf.

[4] Median filter. https://www.mathworks.com/examples/image/mw/images-ex74217292-remove-noise-using-an-averaging-filter-and-a-median-filter.

[5] Gamma correction. https://www.cambridgeincolour.com/tutorials/gamma-correction.htm.

[6] Connected component labelling. https://homepages.inf.ed.ac.uk/rbf/HIPR2/label.htm.

[7] B. M. Bein, S. Berkebile-Stoiser, A. M. Veronig, M. Temmer, N. Muhr, I. Kienreich, D. Utz, and B. Vršnak. Impulsive acceleration of coronal mass ejections. i. statistics and coronal mass ejection source region characteristics. *The Astrophysical Journal*, 738(2):191, 2011.

VI. Appendix

https://github.com/priyankariyer/Parabolic-Hough-Transform

The Physics Society 2018-19

FEYNMAN LECTURE: ''APPLICATIONS OF ECONOPHYSICS IN TAX POLICY ''

By Mr. Priyabrata Pramanik

Econophysics is one of the most rapidly growing interdisciplinary fields that bridges the gap between natural sciences and social sciences. It uses the recent approaches and advances made by physicists in some selected problems to solve the problems of economics.

The Physics Society of St. Stephens College under the umbrella of Feynman Club invited Mr. Priyabrata Pramanik from the Ministry of Finance of India to share his experience with this integrative subject and give an insight about how it is used to combat the challenges of digital economy. In his talk, Mr Pramanik elaborated the various problems faced by the tax policy-makers and administrators since the digitalization of markets has defied all rules based on the old brick-and-mortar concepts of national boundaries. Underlining the fact that Econophysics is already being used in advanced countries like USA, UK, etc., he reinstated that our country needs a refined tax policy to address the dramatically altered global business landscape. He then introduced the various tools and equations inspired by physics that are used to model the new parameters of a changed economic scenario which made the audience wonder as to how simple physics approaches can simplify the complex structures in economics. It was a great discourse and an opportunity to get a glimpse of an entirely different and interesting field of discussion.

- **Mahak Sadhwani**

FEYNMAN LECTURE: “AN ALGORITHM FOR WORLD CLASS SCIENCE”.

By Prof. Deshdeep Sahdev

To continue with the lecture series of the Feynman club - St. Stephen’s college, Prof. Deshdeep Sahdev was invited for a talk titled “The implementation of an algorithm for producing world class science”.

Prof. Sahdev is a Stephanian who trained as a particle theorist in leading groups at Cornell University, university of Pennsylvania and the international centre for theoretical physics (Italy) among others. While at these centres he worked and interacted with several Nobel laureates including Abdus Salam, Ken Wilson, Steven Weinberg and Richard Feynman.

He is a member of the expert advisory group of the device development program in the department of the science and technology.

Concerned with the state of science in the country he works with the vision – “To promote real science in the country”. He talked about his research group at Quazar technologies and told us that all the funding comes from the products he sold, he told that there he aims at producing indigenous products at subsidised rates so that the institutions like IITs’ and IISC don't have to spend billions to buy instruments. He also told us about the STM or “scanning quantum tunnelling current microscope” which works in the same way a blind person would try to paint an image of an object by feeling it. He was very happy for his 41+ installations in various countries starting from Singapore. He explained the need to go to science and nature without intermediaries and to quote himself “art of asking secrets to nature is what science is”.

His vision and dedication towards his work motivates us all to do something good. He has also promised to come back soon to give us something new and informative.

- Rishab Jain

THE RANJAN ROY MEMORIAL LECTURE 2018

By Dr Anuradha Saha

The annual Ranjan Roy Memorial Lecture 2018, organized by the Physics Society of St. Stephens College on 30th October 2018, witnessed a detailed discourse on the topic "Why go to college?" by Dr Anuradha Saha from Ashoka University. The lecture started with Dr Jacob Cherian, the head of physics department, commemorating Ranjan Roy, who was one of his most bright and diligent students. Thereafter, Dr Saha took the dais and led us through an analytical journey of education, economies and scientific developments throughout history, substantiated by a multitude of statistics.

With the advent of the information and communication technology founded upon the world-wide network called internet and branching out into the more advanced forms of machine learning and AI, the human race has been climbing higher and higher on the tree of intelligence, affecting not only the scientific progress but also the social development of people. In these drastic times of smart people and smarter objects, what is the value added by higher education to the human capital?

She spoke about how higher education is not always reflected in a country's progress and goes vain due to lack of job opportunities and brain drain. She expounded on how all the professions do not need a formal education and presented figures that themselves storied out how education translates to earnings, carefully underlining the role of different colleges and their geographical locations in the same. She then moved on to a higher note, quoting the reaction of labour market to major changes in history such as the industrial revolution, she pointed towards the next major revolution that is the coming of artificial intelligence and posed the big question, "Are we ready for it?'. Through a few funny illustrations, she made the audience laugh into the fact that the education system has so far only educated us to read instructions, learn them and take examinations. But with the coming of AI, these jobs will be soon taken over and only the higher end jobs involving creativity and innovation will be left in our cup of tea.

By the end of the talk, she left us wondering if our higher education is actually preparing us for the challenge? It was a great experience which fuelled an entirely new train of thoughts leading us to a relevant direction of future.

- Mahak Sadhwani

THE ELECTRONICS SOCIETY

Young minds are a mutiny of electrons that need to be streamed together to recharge the society with their ideas and innovation.

Established back in 1992, under Dr Jacob Cherian, the "Electronics Society" aka the "E-Soc" is a group of such enthusiastic minds, where ideas, opinions, and perspectives converge in digital harmony. Numerous hands-on sessions on electronics, robotics, Arduino, phoenix boards, etc. are organized where students brainstorm to come up with their own obstacle avoiding bots, tri-copters and also wireless robotic hands with gesture control.

Soon after it was started, it took a computer contract from the administrative office and set-up six computers there as its first footprint in the college. One of those six computers is in use even today. Thereafter, the society helped install land cabling as well as the library database software in college. It also introduced the "JAWS" software, a screen reader for visually impaired students. Bringing in the very first dual Xeon processor was its yet another major contribution to the entire north campus.

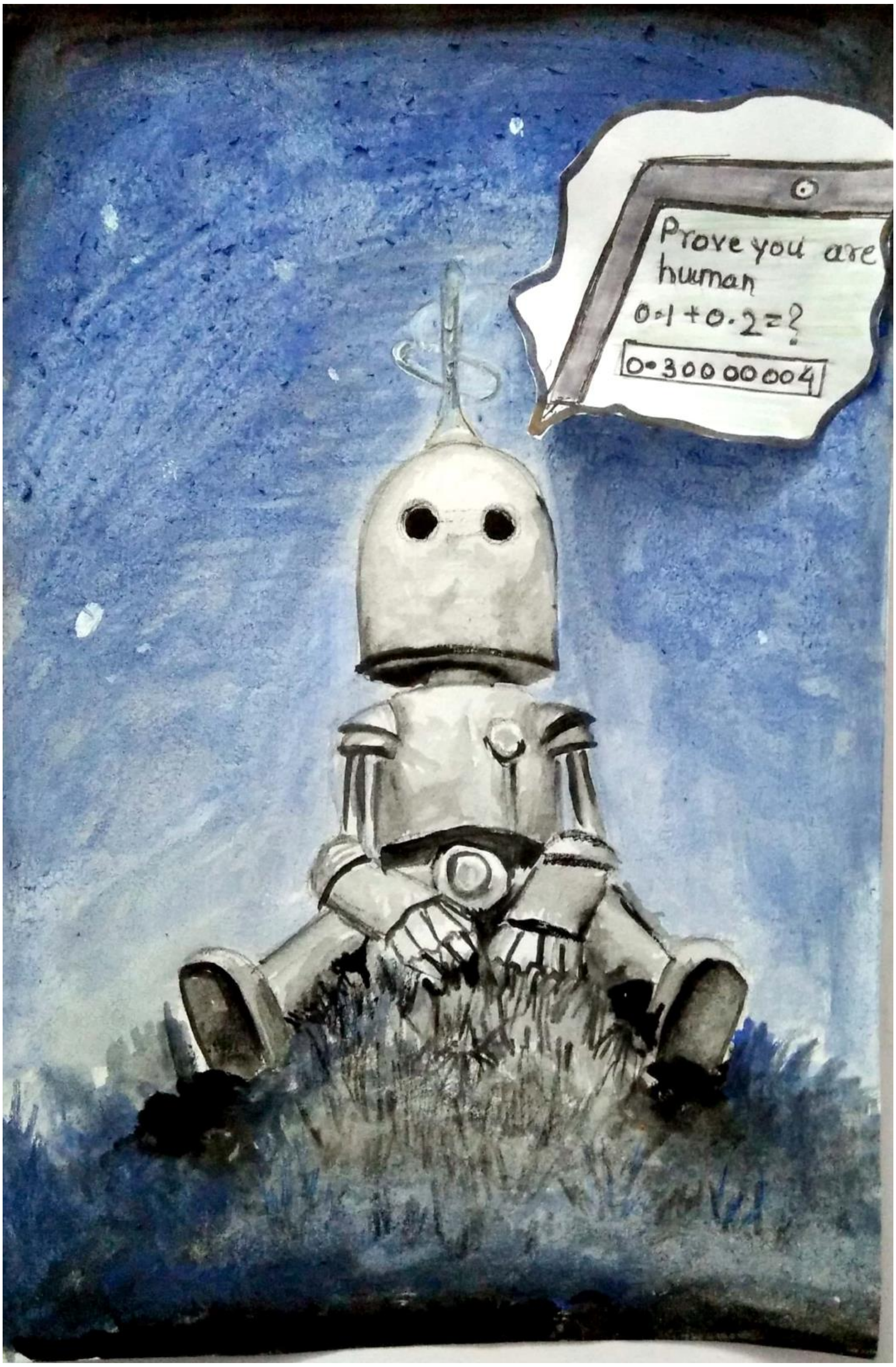
The year 2015 was a milestone for the society. The first major breakthrough was when EVM was designed by the society. Since then, their uses for the SUS elections every year has shown a notable increase in cost efficiency and voter. It has organized a number of games like Junkyard Wars, the science games, circuit making, etc. Among which was the India's first drone racing event on 31st Oct 2015, entirely hosted and sponsored by the E-soc. Over 200 professional pilots and civillians from all over the NCR region unveiling their acrobatic skills. An in-home drone mounted with a camera for aerial shoots were the highlights of the event. The very next year our members won laurels in the inter-college robotic competition at DRDO. The society team also participated in the "Robo wars" held at ITL University Gurgaon. It was one of its kind and the first one to be made in a non-technical college.

Every year a memorable trip to Chandni Chowk marks the beginning of the E-soc session. It is followed by numerous offline and online, tutorial and workshop sessions. For the session 2018-19, a workshop on basic electronics and IoT devices, line follower and many have been planned to organize. A second drone racing event and workshop for school kids is also planned as an annual event. Many society members are also working on projects as ID card scanner for mess and café to avoid coupons and cash transaction. We are also working on EVM 3.0 with a fingerprint for enabling it during voting sessions. Room automation and campus light automation is also being worked on.

We hope that the determination and dedication of the E-soc continues to encourage students to bring noteworthy advancements. We expect some more exciting projects by the end of this academic year.

- **Anuj, Mahak, Sukhveen**

CAPTCHA FAIL



Mahak Sadhwani

A LATE SUBMISSION

-ARUNIMA

If you want to read a story about three years spent in the science block, I am probably not a very reliable and/or an artful narrator. I don't think I can give you an off-beat, scandalous, or a quirky account of this life and I am sure I am not the right person to talk about these three years in terms of the subject knowledge. So, I will offer you what I can.

Disclaimer: The following content may seem boring, mundane and extremely relatable to most of the readers.

I came to this college as most of us do – entranced by the sparkly legacy the name carries, it is just unescapable (not that any of us is complaining). The corridors, gates and the lawns were confusing back then, but I still reached the classes in time (well, mostly). My 'friends' were the people I sat next to in the interview or in first few classes. I never really had a lot of doubts to ask the professors after classes even though I understood much of the class content, unlike now. The Friday Physics Society slots came and went as I struggled to latch onto some little understood content from the Feynman (Club) lectures. Hey, I don't mean to imply that all society activities were a drag; lighting LEDs up in Electronic Society was pretty fun.

Second year: Well, let's just not talk about it. I don't think anyone even wants to read about, especially second years. This is the Voldemort of the years you spent in college. You have settled yourself in a way after stumbling through life in college in the first year and you still have a year to go but there's this year that you just have to get through and the labs are killing you and let's just not talk about it (just like this sentence).

So, as long as I am being completely honest about it, let me say that the only good thing that came out of second year was the camaraderie that we developed in the lab while deciding which pairs in the class would be more compatible and the friendships I found myself to be part of, consciously this time. The workings of the Physics Society were still elusive. Friday lectures came and went, like clockwork.

Well, it’s the last year. I did a research project, helped a bit with the college EVMs, Physics Society is still out of reach, I am still clueless. The attendance has dropped from 90s to 60s. I still hide behind my laptop in the computation labs but still finish the codes somehow. Science Dhaba trips have become more frequent and longer. Chandni finally recognizes me.

Maybe it gets a rosy tint in retrospect, but no one talks about how most of them go from being a 90% attendance ‘futch’ to a just-getting-by-and-craving-attendance-without-turning-up-for-classes third year student.

In spite of all the hopelessness and self-pity that seems to be trickling out of this article, whenever I’ll think about the college in future I’ll think about the times when the whole college would spill out onto the lawns and the sun would shine down with its wintry faded goldenness on the daftly named dogs.

INVITED AUTHORS

Dr Bikram Phookun

Dr Patrick Das Gupta

Mitrajyoti Ghosh

Zachariah Jacob

Abhishek Chakraborty

Mrittunjoy Guha Majumdar

Picture Credits:
Rohit Raj,
St. Stephen's College

The Physics Department, St. Stephen's College, Delhi