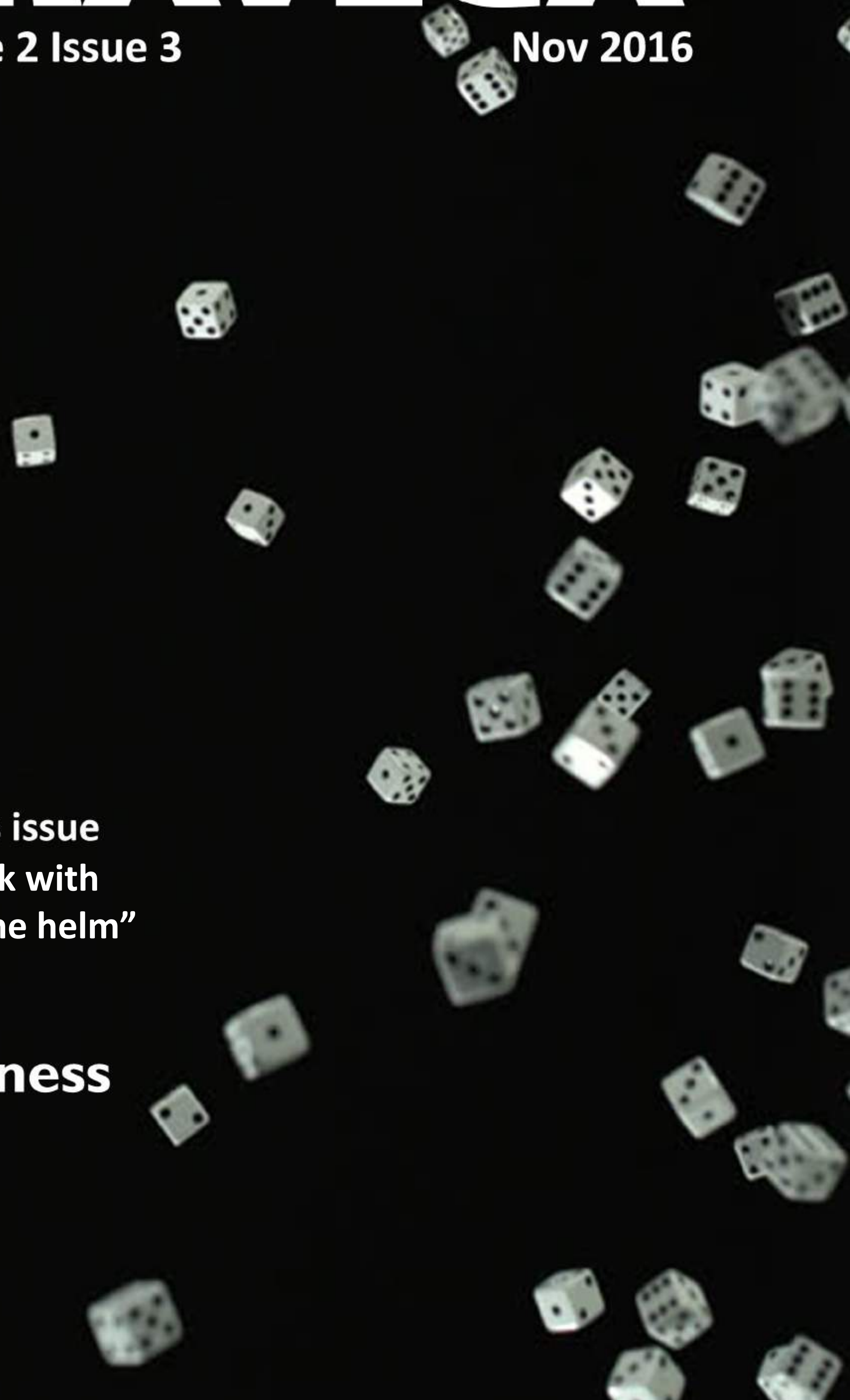
PRAVEGA

Volume 2 Issue 3 Nov 2016



Special in this issue

A insightful talk with "The man at the helm"

COVER STORY

Randomness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EDITOR'S NOTE

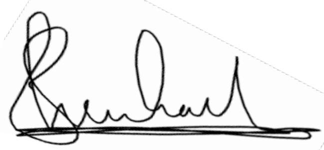
Dear readers,

It is rather fulfilling and an honour to have a loyal audience like you, I would begin by thanking you all for your continuing patronage. This edition brings a new life into the magazine with new colours and most of all, a great interest from the faculty members who were kind enough to take out sometime from their busy schedules and write for us. The departments' alumni have proved that they have not forgotten us and were enthusiastic to share their experiences and interests with us. Above everything we enjoyed making this edition, I hope you enjoy reading it too!

The time is ripe and we are desperate to work more, with things changing fast and all of us running to catch that elusive getaway train and be motivated. As a student or for that matter, in any field of life requires two main ingredients for success; Motivation and Discipline.

Motivation cannot be created, it comes to us so it's much better if we have a tendency to get inspired by what we aim for in life and not fret too much over motivation, whereas discipline comes from within if we force ourselves to work and not give reasons but accept our shortcomings and failures, we won't regret it ever. It's better understood by the lines of Rudyard Kipling in his poem 'If'. I would finish by saying: Work in silence and let Success be our Noise.

I thank you all for taking time in reading this E-zine and contributing to this effort.



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FROM HOD'S TABLE

George Bernard Shaw said "Progress is impossible without change, and those who cannot change their minds cannot change anything". Pravega is undergoing yet another transformation with this issue – a new layout, new sections and lots more contributions. Do let us know what you think of this issue.

At the outset, I, on behalf of the entire department, congratulate Prof. P. Ravindran of our department on taking charge as the Head of the Material Science Department and the in-charge of SCANMAT center. I hope that the department benefits from the collective leaderships of its members on various fronts.

The Perturbations club has been very active over the last few months. The semester began with our senior students conducting some classes for competitive exams, for the other students. Peer learning, as usual, has been a beneficial experience for the students. The club went on to conduct a campus-wide gaming competition of Counter Strike. I was personally overwhelmed by the energy and exuberance of the participants. Kudos to the faculty, staff and student members of the organization committee of the club for these activities.

We now have a "Solve-a-problem" for each working day. A Physics problem is written on a white board near the entrance, and any student who knows the answer can write the same on the board. It has been an interesting experience watching the students reactions to the problems – ranging from confident enthusiasm to absolute indifference! At the end of the day, we have solutions on the board and that, I guess, is all that matters.

We had a seminar on "learning strategies" delivered by Dr K Biju, Department of Education. This was conducted based on the feedback of the senior students that although they have spent more than a decade and a half in learning, they were unaware of learning strategies. Taking down class notes seems to be a herculean task to many students. The seminar was well attended and appreciated by all the students. We do hope to conduct more such seminars.

We now have a small but functional department library. Books for this library have been through (a) cash donations of visitors to department (b) cash donations by faculty of the department (c) book donations by the faculty of the department. All books have been catalogued and are available as reference books in our department library.

Our senior students recently visited the Kodaikanal Observatory as a part of their long-pending study tour. This has been a small effort on the part of the department to satiate the un-quenching appetite of our students for astro physics. There are many more miles to cover before we call it a day. Establishing infrastructure continues to be our prime focus. I am sure that with thew cooperation and enthusiasm of my colleagues and students, we will be able to make large strides in the recent furure.

I wish all the students the very best for the forthcoming examinations. I wish each one of you a happy semester break, merry Christmas, Happy New Year and a very happy Pongal/Sankranthi.

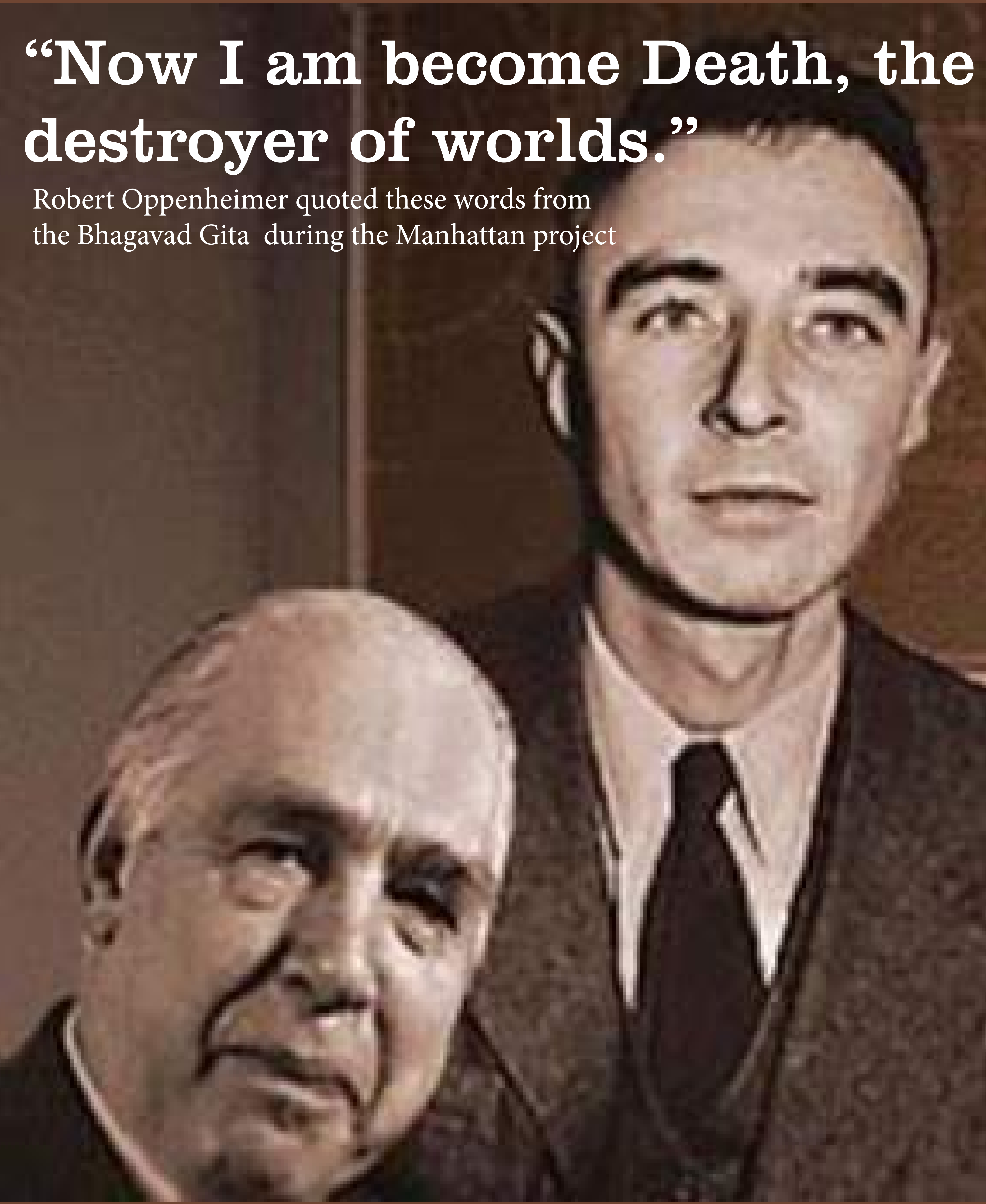
See you soon with the next issue of Pravega.

Dr V Madhurima

Associate Professor and Head
Department of Physics

"Now I am become Death, the destroyer of worlds."

Robert Oppenheimer quoted these words from the Bhagavad Gita during the Manhattan project



Niels Bohr, Robert Oppenheimer, Richard Feynman, and Enrico Fermi. were just some of the distinguished scientists who worked on the development of the atomic bomb (Source: Manhattan Project Heritage Preservation Association)

By Athul K P

We spend a lot of time thinking whether things around us are just random or not. If we want to know any better, we have to know better about random....

What does it mean to be random?

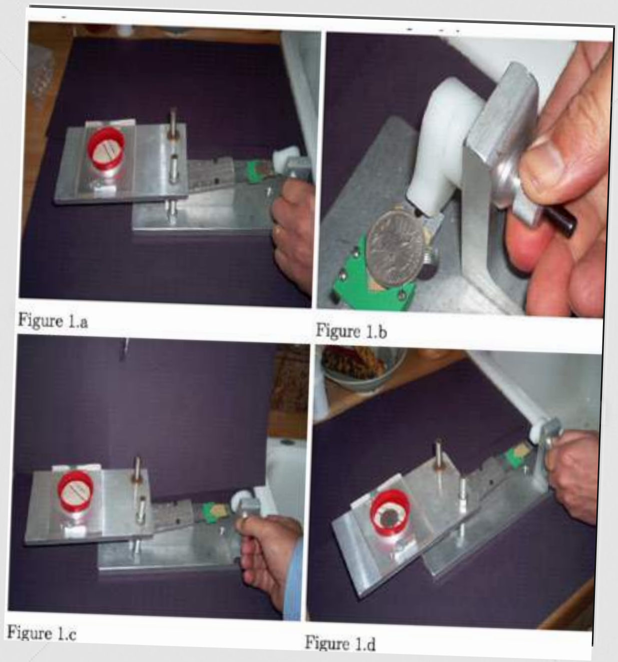
Can something really be random?

A simple definition would be if something is unpredictable, and contains no recognisable patterns, we call it random.

Randomness can range from things that are just hard to predict in advance, like a coin toss, to things that are almost impossible to know a'priori like in which direction a leaf might float as it falls from a tree. To predict that you would need to know the weight of the leaf, the airflow around it, the temperature, tree height and basically a million other factors. The more factors involved, the harder it is to take them all into account. But that doesn't necessarily mean that we can't eventually make a prediction.

So, let's begin our hunt for the most random thing with a coin toss and dice roll.

Coin toss and rolling dice are not intrinsically random, they are only random because of our ignorance. If we could know every initial condition the exact forces and properties that play for a particular flip or roll, we could in principle calculate the result before it even happened. And, sure enough, researchers have built coin flipping robots that can precisely control a flip to get the result they want one hundred percent of the time. Researchers now concluded that coin-tossing is 'physics' not 'random'.

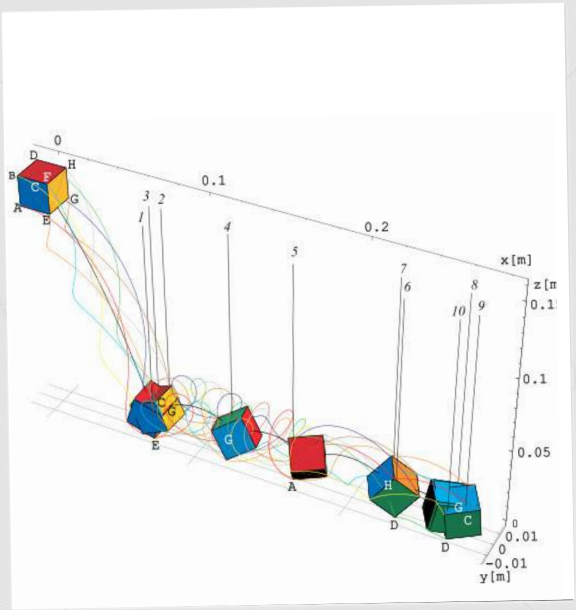


coin flipping robot

(Lets read more about coin toss "COMPUTER SIMULATIONS FOR A COIN TOSS EXPERIMENT,(p57))

In 2012 researchers from Poland and Scotland determined a way to predict die rolls. "Theoretically the die throw is predictable, but the accuracy required for determining the initial position is so high that practically it approximates a random process," said Scotland researcher. They took into account air viscosity, table friction and the acceleration due to gravity. They ran that through a series of complex equations and compared the result to high-speed camera footage of real dice. Using this they managed to develop a system to predict what number of the die would most likely land on. So as of 2012, we now concluded that dice is not necessarily random anymore, at least if you're a scientist.

"coin-tossing is 'physics' not 'random'."



Trajectories of dice vertices calculated from equations.

So, why don't we predict coin toss or dice roll more often?

Well, it's extremely difficult. Insane amounts of precision would be required. The smallest difference between two initial conditions can be magnified over time, leading to chaotic, extremely difficult to predict, results.

Chaos

(Key words : Non-linear Dynamics, Butterfly effect)

A non-linear system is a system in which the output is not directly proportional to the input. Non-linearity is ubiquitous and all-pervading in the physical world. Non-linear systems may appear chaotic, unpredictable or counter-intuitive, contrasting with the much simpler linear systems. For a long time, non-linear systems were essentially studied under linear approximations, barring a few exceptions. However, the famous Fermi-Pasta-Ulam numerical experiments of the year 1955 on energy sharing between modes in An-harmonic lattices triggered the golden era of modern nonlinear dynamics. Several path-breaking discoveries in the followed decades, changed our outlook on nonlinear systems and the underlying dynamics. Lorenz's weather model was one of them.

In the year 1963, Edward Lorenz numerically integrated a simplified system of the three coupled first-order non-linear equations of the fluid convection model describing the atmospheric weather conditions. The bounded non-periodic trajectories of the equations started from two nearby initial states diverged exponentially until they become completely uncorrelated resulting in unpredictability of future state in a fully deterministic dynamical system. Such a solution became known as chaotic and, with this discovery, the field of chaotic dynamics was born.

Chaos or Butterfly effect usually explained by the idea that, a butterfly flaps its wings in Brazil and causes a hurricane in Texas, premise ridiculous. Of course, they cannot do that. There are millions of butterflies if everyone cause the beginnings of a storm, earth would be in chaos.

The thing is, that's not really what the butterfly effect is about. It's about how tiny changes in big systems can have complex results. Systems in this case could

> "A butterfly flaps its wings in Brazil and causes a hurricane in Texas"

be anything from weather patterns, to how big groups of asteroids move, to how lots of people interact, Which does have a scientific name "sensitive dependence on initial conditions".

(Read more about Butterfly effect in Pravega2.2, "Small things matter", by Swetha)

Chaos theory by definition deals with the complex systems whose behaviour is highly sensitive to slight changes in conditions. It appears to be chaos, but it's actually governed by the same rules as everything else in the universe. But because there are so many moving parts it's just impossible for us to comprehend them all. Chaos theory was ground-breaking when it was discovered, because it threw off classical physics. Isaac Newton's laws of nature, equal and opposite reactions and other such theories were all imagined in a clockwork universe. Little change at the start and then a little change at the end. Not one filled with apparent chaos. Basically, he

> "Using a term like nonlinear science is like referring to the bulk of zoology as the study of non-elephant animals."
> —Stanislaw Ulam

thought if we could understand the basic rules of the universe we should understand everything in the universe too, which seems wrong because, even a tiny change in something with as many moving parts as the universe would mean, any assumptions we made would be astronomically wrong and that's super scary.

But the universe is not random. It's governed by rules which scientists have worked on understanding for centuries. Let's take naturally occurring fractals for example, it might seem random but it's governed rules and they show us how chaos is really order. It's an infinitely complex repeating pattern that can appear chaotic

Fractals in Snowflake

Image : Flickr /Maia C

Fractals in Chinese cabbage (Romanesco broccoli)

Image : Flickr /Tin G

at times, but is actually ordered.

Although chaotic behaviour may resemble random behaviour, it is absolutely not random. Chaos theory is an attempt to find order in chaos. The more we understand the math, the better we can predict, how a complex system could react any tiny changes.

The practical applications are huge from understanding the brain to social interaction to how gas moves around in our atmosphere. Turbulence and climate change models keep getting better as we get more data. Because we can harness that chaos math. We get temperature, pressure, volume, mass, solar energy and gas emissions so on... but if somehow a tiny bit of moisture, dust, heat or cold causes a cloud to form somewhere we didn't expect, the whole system can be thrown off which is maddening and that's why the national weather service runs the same weather models again and again and again

Lorentz attractor

tweaking it each time, so eventually they get an inkling of a probability of the true result.

So, when you think of the butterfly effect what do you think of understanding order from chaos? Lorenz used a mathematical tool to find chaos, attractor. It is a point in the ideal multidimensional phase space that is used to describe a system towards which the system tends to evolve regardless of the starting conditions of the system. The Lorenz attractor appeared to spit out chaos until they graft it and it looks like a butterfly. It didn't get its name from an actual butterfly, but from the graph of chaos becoming order.

So here is our next question:

Even if chaos is really just order, is anything in the universe truly random?

Is there anything you couldn't predict even if you knew everything? A process determined by nothing?

The point is, randomness is difficult to identify. It is easier to be certain that something is not random than that it is. But despite this elusiveness sometime people call clearly predictable things random. Like randomly running into your best friend at a popular restaurant. It's not random in a mathematical sense. Both knew about the restaurant, were about to have dinner and wanted to go to a restaurant also were in the same area. Pretty predictable, actually. Perhaps it's just easier, almost a bit of a relief to call things random, so that we can move on to synthesise other information.

If we want a system more random, we will need to find one that is determined by nothing and for that let's look closer. And by close I mean, Quantumly close.

The Most Random Thing

(Key words : Copenhagen interpretation, EPR paradox, Bell's theorem)

Quantum mechanics may have our answer but as always it needs a lot of persuasion before it gives up its secrets. It describes the properties of quantumly sized things as probabilities; "just chances". Not because we don't know enough to be certain, or predict, but because, there's nothing there to predict. There is no beforehand we could know. This is known as Copenhagen interpretation. Quantum mechanics does not provide a single measurement outcome in a deterministic way. It means that, things are uncertain and unpredictable until one measures it. Whether or not a particular individual radioactive atom will decay or not, or whatever the spin of an electron is, the only knowable qunatity once we look. They're determined by a deep-seated randomness woven into the universe itself.

Einstein couldn't believe this. He refused to accept, as he said, that "God does not play dice with the universe." Hence arise the EPR paradox. (Read more in Pravega2.2, "EPR Paradox", Abhijith)

John Stewart Bell rebelled against Einstein's idea with a different approach. Later his theorem was named after him.

Bell's theorem & inequalities

In its simplest form, Bell's Theorem states: No physical theory of local Hidden Variables can ever reproduce all of the predictions of Quantum Mechanics.

Hidden Variables means that there are microscopic properties of fundamental particles that we are unable to observe directly by means of testing, but perhaps if we knew more about them then that might explain the otherwise mysterious behaviour of particles.

EPR provided a proof that says in essence: either there are Hidden Variables, OR particle attributes (such as position, velocity, energy, polarization, etc.) are not real and defined until they are observed. This part is generally accepted, and is simply an extension of the Heisenberg's uncertainty principle. EPR also said that since it is "unreasonable" to believe that these particle attributes require observation to become real, therefore Hidden Variables must exist. Einstein said: "I think that a particle must have a separate reality independent of the measurements. That is, an electron has spin, location and so forth even when it is not being measured. I like

> "I think that a particle must have a separate reality independent of the measurements. That is; an electron has spin, location and so forth even when it is not being measured. I like to think that the moon is there even if I am not looking at it."
> —Einstein

to think that the moon is there even if I am not looking at it." This second part of EPR was accepted by some, and rejected by others including Bell.

Bell's Theorem is based on EPR. According to bell, the Hidden Variable scenarios in EPR impose a critical requirement which was not obvious. Bell exposed this requirement, which is referred to as Bell's Inequality. At first Bell assumed that, EPR is right and local Hidden Variables do exist. And then he showed that local Hidden Variables would lead to a disagreement with the predictions of Quantum Mechanics in certain specific cases.

Maybe at least for once Einstein might be wrong, experiments with entangled particles have shown violations of Bell inequalities.

Entangled particles are particles that exhibit similar properties even when separated by large distances. Now, if they agreed on those shared properties to have, or are somehow determined beforehand to have them, their behaviours should satisfy Bell's famous inequalities and proves EPR (Hidden variable scenarios) is right. But experiments have found that, instead the likelihood of what a machine will see when measuring one particle determines how the other machine will measure the other particle. It is here, when we look that the chance is determined. Explanations for this are even weirder but what the results suggest is that the chance of seeing particular quantum qualities don't pre-exist. They happen when you look. So according to quantum mechanics, the most random things are quantum probabilities.

They are uncertain and unpredictable until one measures it. After all, Quantum Mechanics actually says that an observation does shape reality.

Laplace's Demon

But, true randomness doesn't mean anything. I mean, for us to have meaning we need structure, predictability.

What will happen tomorrow is not random. In other words, it's at least somewhat predictable. I mean, not entirely to be sure, but some things will happen for certain, and other things definitely won't. For example, the sun will rise, water will still freeze at zero degrees Celsius. The point is that we cannot break any laws of universe, and became, Doctor 'Who'. We cannot because, everything in the universe is made of 12 fundamental particles, and they interact in four predictable ways.

What if you were able to determine the positions and velocities of every single fundamental particles in the universe? Well, you would be the intelligence envisioned by Laplace, who thought if you could really figure out where everything is and how fast it's moving, you would know the entire future of the universe, because you know how every particle interacts with every other particle. (The intelligence is commonly known as Laplace's demon). Wow, so nothing would be unpredictable, which means, nothing would be random. Not even human behaviour. Since we are made of the same fundamental particles as everything in the rest of the universe, everything we will ever do, or have ever done, would be determined by the information in the state of the universe at any one time. Again, a clockwork universe!

Don't worry, Laplace demon can be diminished. We can use Copenhagen interpretation or Chaos theory to do that. But we will do it using the second law of thermodynamics.

According to the second law of thermodynamics, entropy in the universe increases with time. But what is entropy? We often call entropy as disorder. It was Boltzmann who advocated the idea that entropy was related to disorder. In Boltzmann's mind, the more ways a system could move internally, the more disorderly the system was. Since dynamic system have more entropy than static system, we can relate entropy as measure of disorder.

Information is fundamentally about order. Obviously, a dynamic system has more information to describe itself than a static system. So, we can directly relate entropy to information also.

Now let's assume for a second that Laplace was right, and that knowing the state of the universe at any one time, means you also know its state at every other time as well. Well, that would mean that the information in our universe would be constant. But if information is entropy, that would mean the entropy of the universe is also constant. And that does not appear to be the universe that we live in.

Entropy in the universe increases with time. But if entropy in the universe is going up, that means the information in our universe is also constantly increasing. That makes sense, because it would take more information to specify the state of the universe now, than right after the Big Bang.

So, where is this new information coming from? My best bet is on quantum mechanics. Quantum mechanics is a probabilistic theory, meaning that you cannot predict with absolute certainty where an electron, say, will be at some later time. You can only calculate probabilities of where you are likely to find it. So, when you do interact with it and locate the electron at a particular point, you have gained information. You now know something that you couldn't have predicted with certainty beforehand.

Fundamentally, a new information is being generated every time a quantum event like that occurs. In that case, it could be these quantum measurements which are driving up the entropy of the universe. They are creating new information all of the time, and that means the disorder in our universe must go up. This is what we observe as the second law of thermodynamics. You know, we often think about the second law as a curse. As though everything which is ordered is going towards disorder. But maybe, it's only in a universe where this law is obeyed, truly unexpected can occur. And that way the future can be actually undetermined. For us really to have free will, we need the second law of thermodynamics.

So, second law of thermodynamics makes the universe less predictable, more interesting. But, if you are ever feeling boring or predictable, just remember that you are made out of octillions of quantum probabilities. Dice that don't tumble in any analysable way we could ever predict. They are the most random thing. God may play dice with the universe, but they are the best dice in the universe.

#Keep calm and stay random!

Credits goes to references and professors

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Acknowledgement

I thank Dr. M.Ponmurugan, Assistant Professor, Department of Physics, CUTN for introducing to the concepts and ideas of Quantum mechanics (PHY062) and corrections of this article.

I thank Dr. L. Kavitha, Associate Professor, Department of Physics, CUTN for introducing to the concepts and ideas of Nonlinear dynamics and Chaos (PHY0E15).

Athul K P
iMSc Physics
4th year

MAN AT THE 'HELM'

On August 6th, 2015 Dr. ADITYA PRASAD DASH joined the Central University of Tamil Nadu as Vice Chancellor.

Professor Dash, a person of significance in the field of Biomedical Science has devoted his entire career in developing various tools, technologies and strategies in helping for upliftment of the society. Credited with a PhD and DSC degrees in Zoology, he has contributed a lot, particularly on transmission biology of tropical diseases.

Some of his notable contributions includes: establishing Anopheles annualris as an important vector in rural areas and identification of telomerase activity in gametocytes of Plasmodium falciparum. He demonstrated efficacy of drug combinations. He was instrumental in proving the efficacy of Mass Drug Administration (MDA) in India. He has also contributed in developing an animal model for chemotherapeutic and immunological studies for parasitic diseases. Besides his research on Malaria vectors, he has also researched on malaria parasites which includes elucidiation of uniqueness of the evolutionary patterns of the chloroquine-resistant gene in P.falciparum. He also has developed a simple technique for detecting dengue virus antigens in desiccating mosquitoes which serves as an important tool for surveillance. Then his contributions on climate change impact on infectious diseases are noteworthy.

One of the major contributions Prof. Dash has made in the field of molecular epidemiology is the determination of high proportion of mixed-species malaria parasite infections in India. And using comparative genomic approaches he has contributed in the basic understanding of how some genes that are responsible for providing resistance to malaria infection are evolving in humans.Apart from Laboratory level research activities, his works extend to field trials of various intervention measures.

He has published more than 250 papers in reputed peer reviewed journals, with high citation index, 'h' index and 'i10' index. In brief, Prof. Dash has contributed to the development of human resources in India which is quite evident from the fact that he has guided as many as 12 PhD students and several post- doctoral fellows who have all become successful scientists in today's date.

The journey that he led many years ago made him play many diverse roles. Prof. Dash has spent about 15 years in training and teaching PhD students and publishing research papers in peer reviewed journals of international repute. He joined the ICMR (Indian Council of Medical Research) unit at Bhubaneswar as a bench level scientist where during this phase he had the privilege of building the Divisions of Medical Entomology & Parasitology which turned to be one of the most productive units in the country. His routine activities included rendering consultancy services to national and international agencies.

Prof. Dash has headed many institutions and has shown tremendous leadership and administrative capabilities over the years. Started as a Director of Institute of Life Sciences at Bhubaneswar, he has spent almost 12 years as Director of different research institutions under ICMR and Department of Biotechnology, Govt. of India. His most challenging phase in leadership was when he was the Director at the Institute of Life Sciences where the institute was addressing some very challenging issues. During his stay of five years, the institute started showing unprecedented progress in terms of its performance. " **The momentous occasion was when the then Prime Minister of India dedicated the Institute of Life Sciences to the nation during the last part of his tenure there on 15th July, 2013"**.

After this successful tenure he resumed the Directorship of the Regional Medical Research Centre (now National Institute for Research on Tribal Health). He has established many state of art laboratories during his tenure as a Director at different institutes and each of these institutes showed enormous growth.

Over the last 20 years, Prof. Dash has been passionately creating platforms for academicians/ scientists to come together and share their ideas as part of his activities. A number of seminars and workshops, etc. also have been organised by him under the aegis of different societies and academies. Apart from these, Prof. Dash also has proven his leadership in the international level. He played a key role in strengthening and establishing research and academic capacities, and networking of centres of excellence in tropical diseases in South East Asia Region. He has delivered plenary lectures at several meetings at global level and organised a number of international meetings in many countries

During his tenure, Sri Lanka, Thailand and Maldives reached the point of elimination of lymphatic filariasis, a disease affecting poorest of the poor. The strategies developed under his leadership are now adopted for elimination of Kala-azar and control & prevention of Dengue.

Distinguished Scientist Chair: After superannuation from the WHO (World Health Organisation), Dr. Dash occupied the "Distinguished Scientist Chair" at the Institute of Life Sciences, Bhubaneswar since 11th May, 2015.

Prof. Dash is rated as top rank in the subject area of Immunology and Microbiology and in the area of Medicine, he is ranked 7th among the top 10 Indian researchers.

To read more about him click here.
Below is an interview with the man himself, talking about this ambitons, passions and more!!

PERSONAL INTERVIEW:

1. As a leading and renowned medical biologist how do you feel knowing that you Indirectly helped thousands of people through your work?

I feel much contended about my work in tropical diseases which affect the marginalized community. We developed various tools, technologies and strategies to for control / prevention / elimination of neglected tropical diseases affecting poorest of the poor.

I am very happy that I am able to help people through my work and it gives a greater satisfaction than any reward.

2. Do you feel happy and is it fulfilling to know that you were ranked as seventh amongst the top researchers in medicine in India?

I feel very happy indeed. DST, Govt. of India, brought out a publication highlighting top researchers in India, based on research publication of various Indian scientists during 2001 – 2014. All areas of Sciences were divided in to 16 categories, I was ranked first in one category (immunology and micro biology) and seventh in medicine. This recognition at some stage gives a great pleasure and I am thankful for it.

3. Why the Low profile then?

I remember Einstein's saying "The monotony and solitude of a quiet life stimulates the creative mind."

I started my career at ICMR in 1978 as a researcher. By 1997 I was the director. After heading five national level research institutes, I left to work at UN. After my tenure in World Health Organisation, I occupied the distinguished scientist chair for few months. Keeping a low profile helps a lot. I work hard and I don't like to show off, I am an introvert and that has paid rich dividends in my career.

I had the privilege to work in several places in India in several research institutes. When people ask me where am I from, I say, I belong to India. I never faced any controversy.

6. When many scientists and researchers prefer to work in developed countries, you have shown interests in working at developing nations why so?

Yes, I am a homemade cucumber! My area of work in transmission biology or tropical diseases, especially vector borne diseases. Tropical diseases are found in tropical countries i.e., developing countries and not in developed countries. India is a gold mine for research on these areas. Therefore, I never felt the need to go abroad for learning research. Instead I had trained many scientists from developed countries on vector borne diseases.

5. Biology is a time consuming science and many a times results are not so promising. How did you manage to do it so well?

I don't agree with that! In my student days biology was called as an innocent science and was very time consuming, but today it is very strong and powerful. After World War II many Physicists and Chemists changed their line of work to biology and made it a vibrant science, so we owe a big thanks to Chemists and Physicists for making biology very attractive.

7. How do you feel about being associated with leading organizations such as WHO and ICMR which are capable of bringing positive change to millions of lives?

Overall I had wonderful experiences. I also worked in the Department of Biotechnology (ILS, Bhubaneswar). ICMR carries out Health Research. DBT is aiming at Research for Health. WHO is an UN organization and is very reach in technical manpower. It is a global statutory body addressing all aspects of Health. So it was an enriching experience for me working with these institutions.

8. How do you summarize your journey from a student to a distinguished scientist then as a Director of many institutes of excellence and finally the vice chancellor?

One should have to fix a goal and work towards it, in my initial life my father played an important role. I was a bare footed student during my school days and in the course of my study my father wanted me to become a doctor as my grandfather was the first doctor in my district. During my initial attempt to study for becoming a doctor I couldn't get an admission due to me being under the age limit (at that time there was an age limit to get admission

in to medical schools), so I started my B.Sc (Honours) and next year I didn't want to study a year below to what I was doing and after that no looking back. I accomplished what I wanted. I always feel fortunate and remain obliged to The Creator of all that is, who probably guided me in silence.

9. During your tenure as Director of ILS, Prime Minister dedicated the Institute of Life Sciences to the Nation. How do you feel about such a rare honour?

It was a scintillating experience and a monumental achievement. That was my first time being a director of an institution and it was very challenging task. Before I took over the institute, it was under the state government then the government of India took it over, the institute's success was so much that prime minister personally came and dedicated it to the Nation. For me it was a very great achievement.

10. With growing responsibilities how do you manage your work life balance?

One has to be very methodical and should have a list of short term and long term goals. Being a part of and as a head of different institutions, I had to know about different traditions, requirements and uniqueness, each organization should have. I try to establish an open-door policy and avoid letting problems linger. To achieve best results, one has to focus properly on their goals.

11. What sparked your interest in life sciences amongst all other subjects?

From the beginning I wanted to be a doctor but I ended up joining a course on Zoology. After that I focused on it. That has helped me a lot.

12. Do CUTN bring fond memories of your student life? Were you a backbencher or a book worm? Who did you fear most in your collage and why?

Definitely yes! I remember my college days very often. I was privileged to study in a renowned college; an old collage with an old history. From my student days things have changed a lot but the essence is same.

I was never a backbencher in my life and that's probably due to my short height or maybe something else.

I was scared of my Sanskrit and Hindi teachers a lot, because I was poor in those subjects.

13. What is your long term plan for CUTN as under your leadership other institutes have become quiet famous?

I will be here for five years and what I want is that my work here should be reflected in the next 20 years. I want to sow the seed which will grow and bear sweet fruits and create an excellent central university to occupy a prestigious place in the global map.

14. What would you like to be other than a biologist and why so?

I can't say. Maybe a movie star. In my school days I was very much into movies and I got letter of admission from Pune for an acting course but my father hid it from me; so I never ventured anywhere else other than life science.

15. What was family's role in your career?

In the initial days my father was a great encouragement and after marriage my wife played a tremendous role and she is an inspiration. I am what I am today because of her encouragements and her sacrifices for my career.

16. Current research and future plans?

Still I publish when I get time, but now it is mainly on policy research. Irrespective of time, always there is a future for everyone.

17. What do you think is the future of scientific research in India?

We are very strong academically and we have many great institutions in our country. The future for Indian scientific community is very bright. However problems like bottle necks, bad politics in science, bureaucracy and lack of appropriate autonomy need to be addressed.

18. In comparison with other nationals where do you think Indian students and scientists are in a position of advantage and in disadvantage?

If I compare our system with even some small countries in Asia, they have a very liberal system of education and research. Our advantages are our manpower, diversity and culture which no country has, and are unique only to us. We have very good labs here in India and as I said our scientists and students definitely have an excellent future.

19. Advice for CUTN students?

- Honesty of labor always pays and single minded devotion brings fabulous dividends.
- Nothing can substitute hard work
- Discourage rumours and trust in facts and time which never betrays.

20. Inter disciplinary subjects are playing a major role in academic scenery. What are you planning In CUTN for the same?

Integrated approach and inter disciplinary work are the buzzwords of success, without information technology and Bio-informatics the human genome program would not have been a success. There are numerous success stories linked to inter disciplinary research. CUTN will soon focus on this.

21. Being a biologist what do you think about physics?

Physics is a very interesting subject. You will see that after 20 to 30 years from now two areas of science will dominate the world of science. These are Theoretical Physics and Materials Science.

22. What is your opinion on physics department of CUTN?

Department of Physics is doing well and it has very good infrastructure and very well informed and excellent faculty members. The students are very competitive. Team work in Physics department will bring fantastic results and tremendous laurels to our University. I am quite happy about their innovative attitude and I wish all other departments start activities like Perturbations (Physics club) and E-magazine Pravega. I will be waiting to see more new innovations from the department in the future.

23. Where do you think your journey will take you after CUTN?

I really don't know. I trust in time, as always and I go where it will take me.

Interview Conducted by:
P Sri Harsha
Athul KP

Let C be a civilisation

By Dr. T. Sengadir
Professor and head
Department of mathematics

The model essay composed by our 4th standard Tamil teacher began as follows: "We keep so many pets in our houses. The dog is one of them". When we wrote an essay on cat, all of us started the essay with: "We keep so many pets in our houses. The cat is one of them". Believe me, we were intelligent enough to replace the sentence, "The dog protects the house from thieves" by the sentence "the cat is fond of milk" and not "The cat protects the house from the thieves". In 10th standard, I was supposed to be one of the most original students of my class. While my classmates would memorize essays from Konar Tamil Notes, I would write my own essays. I wrote an essay on library which began as follows: We see so many buildings in our town. Library is one of them.

I do not think that my writing skills are any better now and my usage of English is coloured by text books on Mathematics. So let me begin this article by: Let C be a civilisation.

Some of you may have heard of the yet to be deciphered Indus Valley Seals. Think of such an imaginary civilisation and assume that some of the symbols found on the seals look like # $ % ^ & *. Say, there are 20 such symbols and we believe that the language is English! (Why not?)
The 20 symbols could have represented any 20 of the current 26 letters of English. Let us calculate the number of all possible interpretations. The first symbol may represent any one of the 26 modern English letters. The second may represent any one of the remaining 25 and so on. Thus the required number is 26 X 25 X 24....... X 7.
Let us further assume that all the words found on the seals are four letter words. Next, we make the assumption that the total number of four letter words is 100. Every four letter word has 26 X 25 X 24 X 23 possible interpretations. Is it possible to use powerful computers to list all possible interpretations of each of the four letter words and hope to decipher the script? I leave it to the imagination of the readers.

Whatever I have described above is a typical mathematical simplification of a complex problem. The issues which make the deciphering of Indus Script complex are the following: The language is unknown and perhaps the symbols do not represent sounds but constitute a pictographic way of writing.

I suggest that the interested readers go through an article on this written by S. Srinivasan, J.V. Joseph, and P. Harikumar published in Current Science. Prominent people who have worked on this problem include Asko Parpola, Iravatham Mahadevan and Gift Sironmony. Refer to the link http://www.sciencemag.org/cgi/content/abstract/1170391v1).

I would like to close this article by declaring that the problem of deciphering the Indus seals is of interest not only to politicians who have deciphered it many times, not only for genuine historians but for also mathematicians and computer scientists.

Organic Semiconductors: Functional Materials for Future?

By Dr S. Nagarajan
Professor & Head
Department of Chemistry

For the past fifty years, inorganic semiconductors such as silicon, gallium arsenide, silicon dioxide insulators, and metals such as aluminium and copper have been the backbone of the semiconductor industry. However, in 1977 the first highly conducting polymer, chemically doped polyacetylene was discovered, which demonstrated that polymers could be used as electrically active materials as well.

This discovery resulted in a huge research effort on conjugated organic materials. In the earlier time, the performance and stability of organic semiconductors were very poor. However, with drastic improvements in synthesis and processing of new classes of molecular materials such as conjugated polythiophenes in the past two decades, the prospects of commercially using organic semiconductors in applications such as organic light-emitting diodes (OLEDs), Organic field-effect transistors (OFETs) and solar cells are now greater than ever. In fact, in 2002 Philips introduced the Sensotec Philishave as the first product in the market featuring a display panel based on OLED technology, and following that, Kodak has introduced the Kodak EasyShare LS633 digital zoom camera with an award-winning OLED display technology. Sony produced 27-inch protype OLED TV with a contrast ratio of greater than 106 and NTSC color reproduction ≥ 100. Simplicity in manufacturing and lower costs of organic devices have been the primary reasons driving these devices towards commercialization. It was suggested that if "the field continues to progress at its current, rapid pace, electronics based on organic thin-films materials will soon become a mainstay of our technological existence."

Different materials and structures are actively being investigated. On the one hand, the research is motivated by new applications for organic electronics that can overcome limitations of inorganic materials. On the other hand, the effort is driven by the intellectual challenges that the investigations of new generation of functional materials offer. This implies addressing new questions, concepts and models that allow the manipulation of chemical, structural, physical properties and device performance.

The field is moving very fast; at the moment researchers are able to control the material properties at the molecular level. They can impose different molecular packing during growth, add side groups that enhance particular properties, as a result of the understanding of the various microscopic contributions to the charge transport. Past investigations were hindered by material instabilities (to environmental conditions and/or processing methods) and structural defects that prevented the measurement and understanding of the intrinsic properties of the organic materials. In the last years, by careful design of new methods that enable the exploitation of the fascinating properties of carbon-based semiconductors, good control of the structural properties and charge density distribution in organic materials is achieved. The degradation is avoided as a consequence of a better understanding of the material behavior in different conditions (temperature, moisture, light) and interactions during processing.

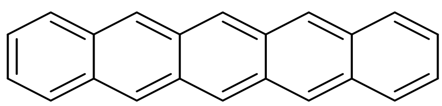
Among the organic materials for electronic applications, the most interested in that class which contain ϖ- electrons. For example, consider ethylene C2H4 molecule, in which the SP2 hybridized carbon forms three co-planar σ -bonds; the carbon atom bonds with the other carbon and two hydrogen atoms. The fourth orbital 2(Pz) is perpendicular to the SP2 hybridized orbital plane, and leads to additional ϖ bonding between the two carbon atoms. The molecular orbitals thus formed split into bonding and anti-bonding states, which commonly are also known as HOMO (highest occupied molecular orbital) and LUMO (lowest un-occupied molecular orbital), respectively. These molecules form solids via a weak intermolecular bonding, clubbed under the name of "van-der Waal" bonds. On account of this weak bonding, although the HOMO and LUMO levels may take shape of an energy band, but the bands are rather narrow.

Furthermore, consequence of this weak intermolecular bonding is that the electronic properties of the organic solids are largely determined by the molecules themselves; role of the weak forces is only to hold the organic molecules together in a solid. An analogy between valence band and HOMO level and conduction band and LUMO is possible. But, the width of the energy bands in inorganic semiconductors is much larger, which has a consequence on the mechanism of the charge transport.

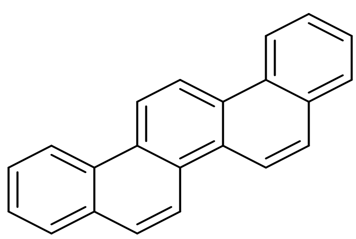
Types of organic semiconductors:

p- Type semiconductors:

1) Molecules involving have high HOMO levels and exhibit electron-donating properties.
2) Typical p-type semiconductors are acenes, such as pentacene, and heterocyclic oligomers, such as oligothiophenes



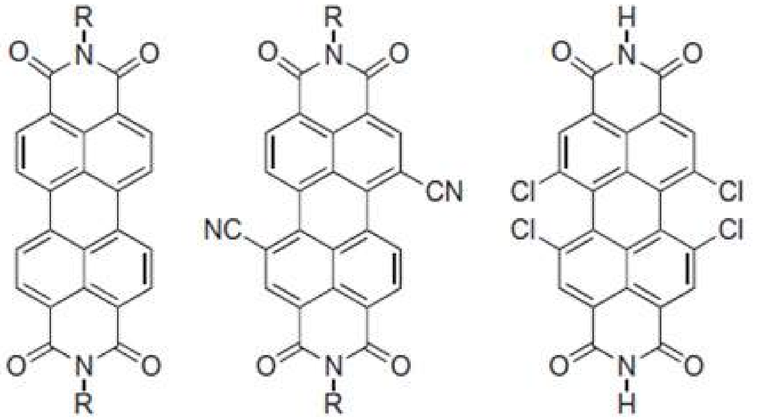
Pentacene



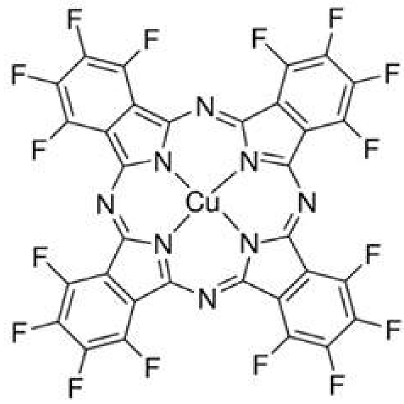
Picene

n-Type semiconductors:

1) Electron-accepting molecules with low HOMO levels.
2) They are labile to oxygen and the stability is related to the electron-accepting properties of semiconductors.



PTCDI Derivatives



Phthalocyanine

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Bubbles, Drops and Nature

By Dr V Madhurima

Associate professor and head
Department of Physics

Have you ever tried to blow soap bubbles? Today, we get fancy frames that contain multiple holes to blow bubbles of various sizes. In my childhood, we had a simple circular or square frame behind which was a straw through which one could blow air to release the bubble from the frame. Bubbles and drops have fascinated many mathematicians and physicists such as Laplace, Gauss, Poincare, Chandrasekhar, Gamow, and Wheeler, over the last two hundred years. They continue to remain fascinating.

One could easily see that the shape of the frame did not matter - the bubbles were always spherical. This is because nature loves to minimise tension! The Principle of least action is among the most elegant principles of Physics. According to this, nature usually likes to take the shortest path when going from one point to another. Light travels in straight lines since a straight line is the shortest distance between two points. In the case of the bubbles, the quantity that nature tries to minimize is what is called the surface tension. When the frame is dipped into the soapy solution, the liquid stretches itself over the frame. This stretched state causes the water molecules to possess an extra energy, called the surface tension.

Figure 1: A bubble and a double bubble

Once the bubble is released from the frame by blowing air, it is no longer constrained by the forces of the frame. At this stage, the bubble is acted upon by two distinct forces - the air in the bubble creating a finite volume to it and the forces on the soapy layer that want to reduce their tension. The bubble tries to reduce the excess energy in the film, for a given volume of air trapped by it. For a given volume, a sphere has the lowest surface area, and hence spherical bubbles are formed - a case of principle of least action at work. Minimizing the surface area minimizes the potential energy of the bubble, and that in turn maximizes entropy.

This can be understood by considering the difference in pressures on the either side of the liquid surface, which is now no longer a plane but is bent. The difference in pressure across non-planar interfaces was formulated by Thomas Young and Pierre-Simon Laplace as

$$\Delta P = 2\gamma / r$$

Where ΔP is the pressure difference on either side of the bubble, γ is the surface tension of the liquid and r is the radius of the bubble. The pressure on the inner side of the bubble is greater than the outer side; and hence the bubble will eventually "burst" to equalize the pressures on either side. If the drop is not perfectly spherical, the equation is re-written in the form

$$\Delta P = \gamma(R 11 + R 12)xydz$$

It can be seen that the curvature of the bubble depends on the pressure difference between the two sides of the membrane-like surface. What this means is the following - in the absence of air, the structure with minimum tension will be a plane. However, when there is a finite volume of air trapped, the minimum tension structure is a bubble. If two such bubbles meet, if the pressure difference on either side is the same, the common surface takes the shape of a plane (R=0), thus leading to a ``double bubble'' [Figure 2].

The double bubble conjecture states that the least-area way to enclose and separate two given volumes is a Standard double bubble consisting of three spherical caps meeting at 120-degree angles.

The one phenomenon that could complete with soap bubbles in piquing curiosity is that of raindrops. One can spend hours looking at them fall as drops,

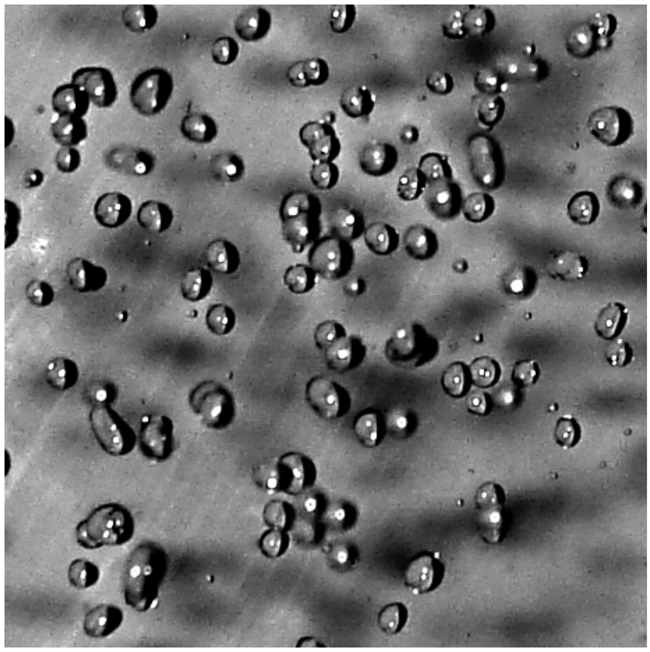


Figure 2: Drops falling under gravity- diagonally from right top to left bottom.

linger on edges, splatter off the roads, sink into the soil and release the petrichor. Raindrops, like bubbles, are spherical in shape if the size of the rain drop is less than a milli meter. At this scale, the influence of gravity is negligible and hence the surface shrinks to form a sphere. Had you observed the raindrop just before splattering, carefully, you would have seen that the shape is not spherical - it looks like a paper-pin with a long sharp tail towards the earth and a blob on the other end.

As the small droplets fall, they collide with other droplets to form larger drops. This happens because when two drops come in contact, the combined system tries to reduce the net surface area. These drops are subject to a tug-of-war between the surface tension trying to reduce the surface area of the water drop, just as in the case of the bubble and the force of gravity trying to elongate it by pulling the drop towards earth. As the weight of the drop increases, the bottom part of the raindrop becomes heavier, since the force of gravity overcomes the surface tension forces. This additional pressure inside the drop caused by the excess water, along with the air pressure acting on it from outside, flattens the bottom part of the drop. The shape of the drop is now like the top of a burger bun - flat on the bottom and bulged out on the top. As this drop further grows and falls, (and reaches a size of about 5 mm), it begins to look like an umbrella - the centre is thin and the sides are heavy. Air pressure makes this drop to break apart in to droplets of about 2 mm.

Did you know that in 2012, David Hu, who is a Mechanical Engineering Professor at Georgia State University, pelted airborne anopheles mosquitoes in a laboratory with water drops to see why mosquitoes are not killed by raindrops. He found that the weight of the mosquito was not sufficient to cause any impact on the falling raindrop. You can read more about this, and also see the video of the experiment at the link given in the end.

Bubbles and drops are of interest to Physicists studying the atomic nucleus - the dense region in the centre of an atom composed of protons and neutrons. The nucleus is also spherical in shape and has a diameter of about 10^{-15}m. What hold the protons and neutrons together? There are various theories, and one of them is derived from the idea of liquid drops and is called, rather uninterestingly, the liquid drop model.

So, raindrops and nuclei both attain a geometry close to that of a sphere, since there is a minimization of their respective surface energies. Much like the water drop, when the volume of the nucleus of the atoms is small, they can form a larger nucleus. This phenomenon is called nuclear fusion and is responsible for the energy generated by

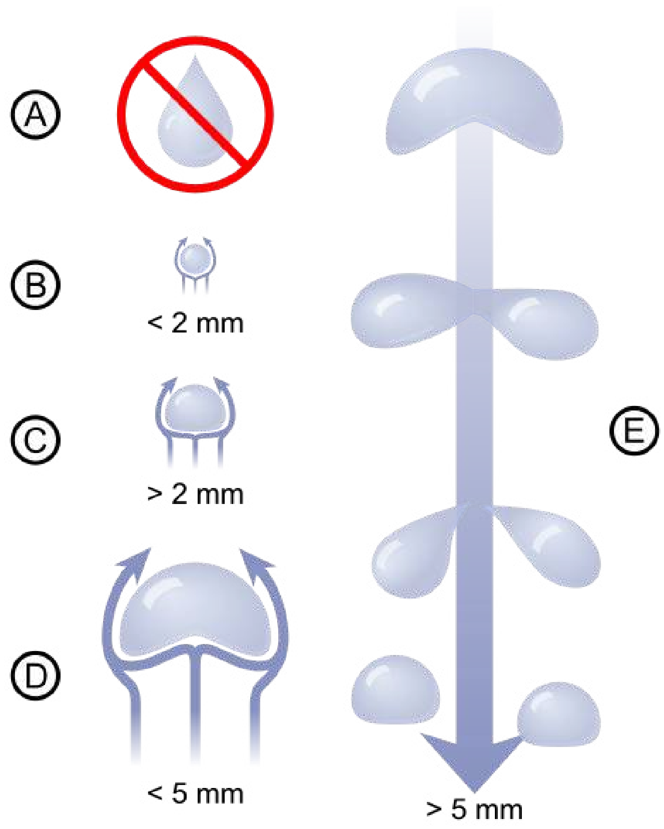


Figure 3: Stages of a drops falling under gravit

Sun. On the other hand, larger nuclei will split into smaller ones, releasing energy. This is known as nuclear fission and is the basis for operation of our nuclear power generators.

The original principle of least action was proposed by the French Mathematician, Peirre-Louis Moreau de Maupertuis who supposedly said ``Nature is thrifty in all its actions'' and went on to prove the laws of reflection and refraction from it. There is a certain elegance to thrifty action, albeit only those that nature performs.

Before we close, let me leave you with a few fun facts about bubbles. Did you know that:

•A Swiss professor, Dr Dr. Natalie Hartzell has theorised that children who play with bubbles have better motor skills?

•You cannot form a bubble in space there is no external pressure to counter the pressure within the bubble? However, there are experiments to prove that you can form bubbles under microgravity conditions.

•400 year old Dutch paintings depict children blowing bubbles using clay pipes?

•Bubbles formed below -25°C can freeze, and subsequently shatter?

•Blowing large bubbles is a well-established street art form, especially in Europe?

So, the next time you see me blowing bubbles in my office, bear in mind that I am merely doing my research! I would love to hear from you, mail at madhurima@cutn.ac.in

Link's:

•http://phenomena.nationalgeographic.com/2015/06/24/raindrops-keep-falling-on-my-head-a-mosquitos-lament.

Let us grow ears to hear the heartbeat of our earth - Geophysics

By Dr.S.Vijaya Lakshmi

Assistant Professor (On contract)
Department of Physics

Mankind is in search of living possibilities on Mars and existence of life beyond our solar system by the knowledge of our modern physics and sophisticated detection techniques and facilities. However, for our existing place Earth, physics still in its infancy while predicting earth quake.

Earth's Shell structure has been classified as crust, upper mantle, lower mantle, outer core and inner core. Earthquakes are caused in the "fault zone" which comprises many faults in the crust. A fault is a fracture in the earth's crust causing loss of cohesion and accompanied by displacement along the fracture. The force, or stress, exerted on the rock may cause a change in shape or volume of the rock, called strain. Due to severe shear and strain there is slippage of faults and release of energy stored which causes the earth quake in the seismic zone.

At first thought, it might seem that the studies on stress and strain are enough to predict the earth quake. However, the matter densities affected by strain is the key factor. Normally earth has some normal matter density along with electron matter density in all regions. The accumulation of electrons during β^-decay results in electron matter density. β^-decay is a usual happening inside the earth due to the rich abundant Uranium (U) or Thorium (Th) in the crust and mantle.

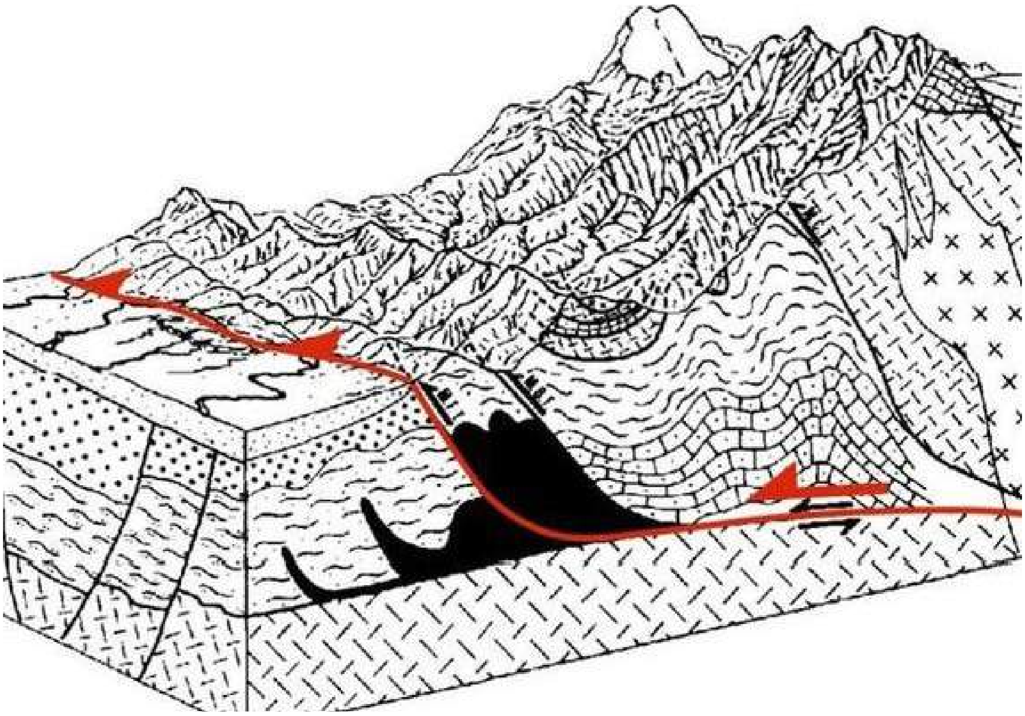
For example,

$$^{234}Th_{90} \rightarrow {}^{234}Pa_{90} + e^- + \nu_e^-$$

In fault zone, prior to earthquake, intensive gas discharge occurs at the crust due to the continuous strain and it leads to the electron density distribution. Hence, the knowledge of matter and electron density is necessary to analyse the possibility of predicting earth quake.

It is interesting to observe that during β^-decay, anti-neutrinos (ν_e^-), so-called Geoneutrino has been produced along with the daughter nucleus and electron. The observations of Geoneutrino could provide the details of density distribution and may help the earth quake forecast.

Neutrinos are electrically neutral particles with a very tiny mass and the interaction of neutrinos with ordinary matter is very weak. This particle is used as a probe to identify the redistribution of electron density via the neutrino Tomography which is based on neutrino oscillations. Neutrino oscillations can occur if there is a mass difference between two neutrinos. The same effect has been expected among antineutrinos also as antineutrinos are just the anti-particles of neutrinos. Antineutrinos emitted from nuclear reactors are used as a probe to detect oscillations. As antineutrinos travel through the identified earthquake



region, a variation has been observed in the matter effect on the antineutrino oscillations. Thus, the electron density distribution which favours the earthquake has been analysed by the measurement of antineutrino oscillations. It is still a difficult task to make an earthquake forecast using this scheme, though it seems to be possible to detect the variations in matter density. It is because of the anomalous electric field appears only several days before the earth quake so that it makes the detector hard to collect the data.

Geologists and Physicists are still in struggle to make a valid model to understand the earth. A constructed reference model which is based on seismic data assumes that Th and U are absent from the core. Hence, the abundance of radiogenic species remains uncertain. At present, an accurate model of matter density does not exist in Physics. The contribution of anomalous electron matter density in the determination of final matter density is yet on debate. Physicists need to know about the speed of earthquake waves through the earth and the density distribution of the earth. The theoretical model made by the physicists does not unfold the mystery of the earth yet.

This is the time to recall Richard P. Feynman's statement, "Physicists have been unable to get a good theory as to how dense a substance should be at the pressures that would be expected at the center of the earth. We do much less well with the earth than we do with the conditions of matter in the stars." Yes, we are going up in "Astro Physics" but coming down in "Geophysics". The heartbeat of our earth is so secret. Shall we take an effort to hear it?

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KNOW YOUR FACULTY
Prof. Dr. P. Ravindran

Professor in Physics and Head of Department of Materials Science
Central University of Tamil Nadu, India

Adjunct Professor, Center for Materials Science and Nanotechnology, University of Oslo (Shangai Ranking 58), Norway

Prof. Dr. P. Ravindran started his life from a remote place near Kanyakumari where he spent most of his childhood days and then completed his B.Sc in Physics in the year 1987 from Madurai Kamaraj University, after which he went on to Anna University, Madras, where he did his Masters (M.Sc Physics with specialisation in Materials Science and done his dissertation entitled: XRD and SAXS investigation on YBa2Cu3O7-x) He has done his Phd in Computational Condensed Matter Physics in 1996 on "Electronic structure, Phase stability and equation of state studies on structural and superconducting intermetallics". He has done his Research Associateship at IGCAR, Kalpakkam before moving to Uppsala University, Sweden as Guest Researcher in 1996. In 1998, he moved to University of Oslo, Norway as post-doctoral fellow and established computational based Materials Modelling activities. In University of Oslo, he was promoted as Associate Professor and then Research Professor (Forsker) and continued this position until he moved to Central University of Tamil Nadu, India as Professor and Head in Department of Physics

He has been rewarded with lot of highly acclaimed awards like, he is the Steering Committee member of European Science Foundation, -Ψk Network- Representing Norway, elected as a Fellow of the Academy of Sciences, Chennai, India in 2014, Adjunct Professor in University of Oslo, etc. to name a few. He has a very authoritative commandeering over administrative system too. Apart from these, he has held different positions and played different roles in the administrative field, like by being a Registrar (Acting), a Chairman, Member of many elite societies, member in CUTN statutory bodies such as Executive council, Academic Council, Building Committee etc. He is also the coordinator for Indo-Norwegian collaborative program on Education and Research funded by UGC, India and SIU, Norway. As an Adjunct professor in University of Oslo, Norway, he organises workshops, provides advanced level course on "Ab initio modelling of Solar Energy Materials" for master and PhD level, setting up computational based lab, writes research proposals, etc., during the vacation period and has also been evaluating project works since 2012 onwards.

He has a very keen understanding on the high perforation scientific computation techniques and has developed a lot of computer programs to analyse, and get a better understanding of the properties and processes in advanced functional materials. He is a true advocate of renewable energy and has contributed a lot to sustain the environment, and adopted many mitigation policies, etc.

He has also been refereeing articles to many International Journals and till date, the count is more than 30. He has also served in a few eminent Editorial Boards:

1. Chairman of the Editorial board for World Journal of Condensed Matter Physics, Scientific Research Publishing (www.scirp.org) 5005 Paseo Sego via, Irvine, CA 92603-3334, USA
2. Editorial Advisory Board member for The Open Condensed Matter Physics Journal (ISSN: 1874-186X) www.bentham.org/open/tocmpj .

He has also been refereeing research proposals for the following:

1. National Science Foundation (NSF), USA
2. Department of Energy (DOE), USA
3. Department of Energy-Basic Energy Sciences (DOE-BES), USA.
4. Indian Institute of Technology, Kanpur, India
5. Solar Energy Research Initiative (SERI), DST, India
6. Preludium founding scheme of National Science Center in Poland

He has published works in around 136 international journals, with 5 papers under preparations and about 8 conference proceedings and more than 5000 citations.

PERSONAL INTERVIEW:

1.Tell us about yourself, right from being an academician to administrator.

I grew up in a normal family, had lived a normal childhood in the countryside and was involved in agricultural activities, apart from schooling. Even did my schooling from government school in Tamil Medium in a remote village. Then I did my MSc and Phd from Anna University. So when working as a research scholar, I was involved with various administrative activities. Administrative experience didn't just came like that, it came from where I studied say, during my PhD(6years), I was engaged in lot of administrative works.

I was involved in NSS coordination activities, then during my years of post-doc, I was periodically organising workshops, getting engaged in both scientific and administrative works. Maybe, I got some experiences from world ranked universities for instance, organising parties for visitors to the institute, bringing Scientist for conducting seminars, workshop management and etc. that helped me gained my administrative experience.

At university of Oslo, which is ranked among top 100, I was conducting Industrial summit, periodic group meetings, etc. Then I had been the head of the theory group, where I have gained lot of administrative knowledge. Then if you are a group leader in University of Oslo, you have to engage in lot of administrative works, like arranging the offices and labs for PhDs, postdocs, visitors etc., purchases for labs, making every thing works without any assistance-ship from others. But in CUTN, administrative experience level is completely different, in fact, I am often facing a lot of challenges. The administrative system in CUTN need lot of improvements to function efficiently. For example, E-based file management system is key to have efficient administration. Here in India, everybody believes in British-introduced hierarchy and the system is strictly following the same without much refinement. I feel that socialistic democracy in Scandinavia is a better system than the current system of democracy in India which brings huge inequality. We are spending most of our valuable research time to track/process files, settling bills etc. and this in turn has impact on the time factor with very limited time to promote research.

2. What inspired you to take on physics in the first place? Do you have any role model? Or a life changing incident?

I always read a lot of books and broaden my horizon. And I personally think that broad knowledge with perseverance is very very important to get into advanced research. Since childhood, I had been a keen reader of lot of nice science books. Then during my masters in 80s, computers started rolling out, which very much fascinated me. Then there was my school teacher plus the interest in science, which motivated me to take up physics so as to understand the various ways of the nature and how it deals.

3. What are your hobbies and memories from your school days?

My hobbies would include Agriculture, planting trees for a better environment., fishing in ponds, walking in beach etc. I can identify around 100 different varieties of banana and 40 different types of mangoes. Apart from that, my hobbies would include swimming, climbing tall mountains, trees (mostly village oriented) and obviously, to practise science. I also explore cooking, although not an expert.

4. What made you choose Materials Science?

I have done my bachelor and even my masters in Physics. Then I saw that chemistry and all the interdisciplinary courses which if works together can really change the world. I always believed in development and physics really interested me as how we can contribute to the society using advanced functional materials, renewable energies, etc. As how we can contribute to the environment and build a better one to live in, and work towards controlling environmental pollution and lot of other things.

5. You work hard from day to night, how does your family handle your late-night working hours?

Research is not time-bound. Ideas will come in the dreams, during bath or anytime. As my wife is also a scientist, both me and my wife usually work together. We enjoy doing research even on Saturdays or Sundays and especially work late nights to prepare research proposals to funding agencies in short notice. I believe that apart from creativity, knowledge and analytical thinking, hard work as well as perseverance are basic requirements to become a good scientist.

6. Tell us about your European experience and how India is lagging behind in Research capabilities?

It has been a really nice experience over there. People are very dedicated, more inclined towards the safety and cleanliness of the environment. I have noticed that they always believe in team work to crack hard scientific problems collectively.

I always want to develop new materials, with properties beyond the current state-of-the art with multi functionalities whether it is nanotechnology or other, so there whenever I develop something, I call up my colleagues and work together with them. I also feel that in Europe one gets more academic freedom and get rewarded when progress is made.

Interdisciplinary subjects collaboration could have a lot of impact. Here in India, we lack resources to do cutting-edge research and even existing resources are usually not shared fairly or underutilised due to lack of proper planning. Also I feel that in publication front usually we give importance to quantity rather than quality. Moreover, the younger generation is interested to study job-oriented courses such as IT, BE or BTech and not sufficient number of talented students are coming to pursue science. I hope this situation will change soon.

Also, we should promote application oriented basic research so that we can develop technologies of our own. Further, there is very poor federal funding in India compared with Europe that makes it very difficult for us to compete with the western world in order to do advanced research for societal need.

7. Can you tell us about your ongoing projects?

Yeah, I have been working under a lot of projects dealing with properties and processes of advanced functional materials useful for energy, environment and emerging technologies. We are currently working on Photocatalyst to convert water into fuel, developing efficient solar cell materials, hydrogen storage materials, Li-ion battery material, magneto electric materials, thermoelectric materials etc. I am keen to promote interdisciplinary research and hence we have recently established an interdisciplinary centre called Simulation Center for Atomic and Nanoscale MATerials (SCANMAT) at CUTN. I am also periodically organising conferences and workshop to motivate younger generation to move to science. I am waiting for the High performance computational facility in CUTN to anchor my research for the last five years. I hope it will be realised soon so that I can start my research activities with resources from India.

8. What is your current area of interest?

I am interested to develop magneto caloric materials for efficient refrigeration, nano materials for biological system, develop new computational tools to design materials to mitigate climate change, etc. Apart from those, I am keen to do research on anything related to the development of the society and sustainability of the environment.

9. What is the future of material science and is India ready?

It's a new domain where we see new development almost everyday. We are establishing, discovering new materials almost everyday now. Right from the stone age time, India has always been a key promoter of new and enriched materials. Yes, I think India is ready and lot of success has also been seen during the past few years in material science and yes, India is advancing, although the process might have been slow.

10. You are a senior advocate for renewable energy. Do you think it is the key for India's development?

Yes, India is importing 70% of its energy from abroad and hence it is very important to promote renewable energy technologies in India. This involves energy generation, storage and utilisation and in all these three areas we need mission oriented targeted research. But, unfortunately, in my view it is currently lacking. Even for the traditional solar energy harvesting, we are depending on the imported solar panels. I hope the scenario will change during Modi's era.

11. What are the hurdles/ obstacles you had to establish your research activities in CUTN?

Making people here believe in interdisciplinary subjects was dfficult and developing a culture of collaborative research were initial challanges. For example, in Uppsala University in Sweden or Denmark Technical University around 100 scientist working in a single group on computational material science. We need a collective growth and also industry participation so that these research goes to society level also.

Computational Techniques is now one of the pillars of modern science like theories and experiments. With HPC facility one can do same level of research as that in Harvard, MIT, etc. In CUTN, even after my 5 years struggle to establish HPC facility I am unable to succeed though I have submitted a proposal to the 12th five year plan once I joined in CUTN. One cannot do computation with paper & pencil or palm leaves with knife. I moved back to India with lot of ambition and visions to transfer my scientific knowledge to young minds in India. But, till date I am unable to establish the scientific computational facility or even a computational teaching lab due to lack of fund. I have expected that any newly established University will give priority to computational based research because it is more easy to establish than expensive experimental facilities. I have expected that scientists will be respected in India and minimum facilities will be created in reasonable period of time. Unfortunately, the current happening makes me feel that the situation is not yet changed in India to promote science.

"One cannot do computation with paper & pencil or palm leaves with knife"

What CUTN needs is a high-performance computing facility to promote interdisciplinary research. Also, we need computational based teaching labs to teach younger generation how to design materials in computer rather than in experimental lab. Also, I have submitted a centralised synthesis facility and instrumentation facility for CUTN in 12th five year plan. It should be established immediately to promote trans-disciplinary collaborative research.

12. What are the challenges you are facing to promote renewable energy research activities in India?

Energy utilisation is directly related to environmental degradation. So, I have proposed to create a Department of Energy and Environmental Technology in the 12th five year plan almost 5 years back. Though we have statutory body approval to launch this department in 2014 itself it has not yet started. I hope the current leaders will give priority to establish the Department of Energy and Environmental technology soon. Also, I am expecting to organise periodic workshops to bring awareness among students on renewable energy technologies.

13. Your area of Science sees development everyday, how do you keep yourself updated?

I read a lot. I am having a collection of around 50,000 eBooks and 1000 theses. I have a very good collection of research articles collected from the past 25 years. Nowadays, Internet is the key source and I am in various research networking sites, mailing list in various computer based research programs. I am often organising and attending conferences, workshops and delivering lectures. Usually, earlier I used to go through every journals, e-print archives thoroughly. But due to tremendous development in publishing articles in huge number of journals, books, conference proceedings etc. in recent year. I now rely mostly on databases such as INSPEC, ISI-web of knowledge, psi-finder etc. I am planning to host the huge collection of my scientific articles in the recently established SCANMAT centre for the benefit of motivated students soon.

14. Why teaching when you could be a full time scientist? How do you manage between teaching and research?

My mission in India is to impart my scientific knowledge acquired from world leading universities to younger minds in India. Teaching is the important media to transfer my knowledge. Also, my philosophy in teaching is "Teach while Hatch" i.e. any new development that happens in science should be transferred to students through teaching immediately As a scientist, I keep my scientific knowledge up-to-date to compete with others, and my teaching philosophy thus fitting with my research activities. So, usually I update my teaching material regularly through web resources without depending on any text book and give my teaching input as ppt files to students through my home page. Also, if one notice my research publications, I always change the field and hence my research area is very broad. So, my research activity is complementing my teaching. Also, teaching is very interesting experience for me and I am learning lot of new things like from even my students as I prepare for my each lecture.

15. What is your most rewarding experience till date?

I would say each and every moment of my life had been rewarding for me. With different phases of my life, it has taught new and different things and helped me had a better perception of the world. All the opportunities are coming with the price tag of challenges. Each challenge is giving me a lot of experience and making

> "Teach when Hatch"

my life active.

16. What would you have been if not a Physicist?

Maybe a law professional or scientist in agriculture or would have done a BSc in Agriculture as I got admission in BL and BSc(agri) after I joined as an MSc student. As I am a workaholic who believe in hard work and perseverance, I have confidence on myself to excel in any field I involve. Its not just like I would have landed up taking up a job in BL Law or other but anything which contributes to the development of society I always want to do and I hope I am currently doing.

17. What do you expect from your students?

They should believe in interdisciplinary studies. They must be punctual and disciplined in whatever work they do. They should never limit their knowledge and always try to broaden it and expand and explore.

18. What is your opinion about the present teaching method?

I think it is going on the right track. But the teachers should always be up-to-date. Things should get upgraded from Traditional studies to Interdisciplinary studies. I am expecting more transparency and accountability. I would expect a course hand book for each courses offered in CUTN. All students should have access to the full syllabus. Students should have more freedom to express their opinion so that they can broaden their knowledge. I feel that the traditional teaching methods and the current evaluation system is making the student afraid of expressing their views freely. For the benefit of the students, I am expecting that all the course study materials should be hosted in course websites as I have done for all my courses. As every subject contents are changing very fast in recent years I could say, “Teach when Hatch”.

19. What are the qualities that you think describes a good independent researcher?

A researcher might not be a genius. But he/she should have addiction for reading, graving for new knowledge, sincere, hardworking, dedication and perseverance.

20. Any advice for CUTN students?

CUTN students, don't just limit yourself to the classroom knowledge alone. None can stop you from enhancing your knowledge by reading outside your syllabus. Internet has open-up the new world of knowledge and use it constructively. There is lot of developments happening currently and hence don't just limit yourself only to the classroom notes. Try out expanding your knowledge, explore the area of your interest because every topic is interesting, it's just a matter of perception and then nothing can stop you from achieving your goals.

21. What are your future goals and aims?

As the Tamil poet Valluvar say "Set your goal highest". Also, Swamy Vivekananda say that "Arise, Awake, stop not till your goal is reached". I always believe in those. I was initially planned to create an University of my own to implement my vision. So, I am now thinking to set up an International Centre for Computational Sciences on par with ICTP, Italy. I feel that the life is very short and every moment we live we should contribute directly or indirectly to the development of the society either through our advanced level research or through all the other means including clean and green initiatives which I always like to do.

Personal interview was done, edited & compiled by:
Arunav Das.
iMSc Physics
4th year

Hamburger

By Murali Krishna

Murali Krishna is a former student from CUTN (I MSc Physics), currently working as Research associate at Center for Free-Electron Laser Science, Hamburg, Germany.

Hello CUTN! It is my pleasure to be a part of PRAVEGA and to share my views and experiences as an aspiring student. Einstein once said, "Only two things are infinite, the universe and human stupidity, and I'm not sure about the former". Hesitation to ask questions seems to be hurdle for most of the students because they are anxious about sounding stupid rather than clarifying their thoughts. But most of us forget to realize that not asking questions will never suppress our curiosity.

I am Murali Krishna, a Research Associate at Deutsches Elektronen-Synchrotron (DESY) and also pursuing doctorate at University of Hamburg, Germany. I did my Master's in Physics from CUTN and graduated in March, 2015. Undertaking research in an internationally acclaimed university was my dream for a long time. There are numerous ways and means to get enrolled for a PhD in a foreign university, especially in Europe. Most of the universities in Germany are world class institutions and one can complete his/her Ph.D. in just 3 years. Other than universities, one can also apply through Max Planck institutes. Germany provides one of the best environments to pursue career in research and also Ph.D. along with employment, like in my case, comes with attractive pay scale for a Master's student too.

To pursue research in DESY, a world class research centre in Germany, will definitely be a dream come true for all the students. DESY uses particle accelerators to study the basic structure of matter and mostly the research is carried out in three major fields of science and engineering: Particle and High energy physics, Photon science and construction of particle accelerators. There are approximately 2000 people employed at DESY, out of which around 650 are scientists and more than 700 are graduates and post-docs, and most of the research in high energy physics with elementary particles has been taking place in DESY since 1960. It also has FEL (Free Electron Laser) source and recently DESY is in the process of setting of XFEL (X-ray Free Electron Laser), which will be functioning very soon. DESY has people from all over the world and there will be many social activities to bring them together which encompasses the idea of DESY's unity in diversity; every week there will be BBQ for all the Ph.D. students along with some drinks. DESY also organises Christmas celebration and summer festival every year, which will have cultural activities with multi-cultural cuisine.

I am working with Dr. Robin Santra, one of the directors of CFEL (Centre for Free Electron Laser), head of the photon science theory division. He is one of the best scientists in the field, with numerous publications. Including myself there are 8

Ph.D. students, 7 Post-Docs and few more Master's students. Research is been carried out in Ab intio X-ray Physics, Chemical Dynamics and Complex systems. We also have some in house codes namely Xatom, Xmdyn, Xsync, Xhydro and Xpyder. I am involved in the implementation of Semi-classical Field Induced Surface Hopping to the code Xpyder. We use C, FORTRAN and Python to develop these codes and I have been using quantum chemistry tool like GAMESS-US and MOLCAS to take care of the quantum calculations of the many body quantum system. We also take summer students every year through the DESY summer student's programme. Every student here, will be part of certain graduate schools, which makes sure that each and every student is provides with necessary resources to carry down Ph.D. It also organises seminars lecture series for the students and scientists. Every group head makes sure that his/her group members are facilitated with enough resources, like getting licence to the required soft wares, buying books for the group, getting laptop for individual students if required and also few leisure activities like sightseeing in and around Hamburg.

Murali Krishna along with his group members of CFEL Theory division

Most importantly DESY is located in Hamburg, which makes it more and more interesting. Hamburg is one of the biggest cities in Germany as well as in Europe. Hamburg is very well known for University of Hamburg, which is also works in collaboration with CFEL and all the graduate schools, which I have mentioned earlier. University of Hamburg was founded in March 1919, and from then on it is been growing as a biggest research and education institute in Northern Germany. Each and every student working in DESY gets enrolled with University of Hamburg as a Ph.D. student, which has various advantages besides research and education. Every student gets a University of Hamburg student's card that offers free public transportation throughout Hamburg. Every student will also get concessions in Movie halls and all the sightseeing places in whole Germany. It also gives discount to buy electronic gadget for the students, like Mac Book and iPhone. Apart from education and research, Hamburg is also famous for its night life. Reeperbahn and St. Pauli are considered as Amsterdam of Germany. During weekend, these places will be filled with people throughout the night which brings life to the city irrespective of time.

I can certainly say without any introspection that Germany is one the best countries to do research in science with a fully equipped scientific ambiance. Also international students are ensured with preliminary needs right from accommodation. Initially one has to struggle little bit to get used to the climate, but once we get over this phase, life in Germany is AMAZING!

Hello all, below is an opportunity for aspiring students, hope you will make the most out of it. Please contact me at "murali.krishna@cfel.de" for any queries and use the links below for further information.

The International Max Planck Research School for Ultrafast Imag-ing & Structural Dynamics (IMPRS-UFAST) is looking for excellent candidates with interests in the physics and chemistry of ultrafast phenomena to apply for PhD positions.

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The International Max Planck Research School for Ultrafast Imaging & Structural Dynamics (IMPRS-UFAST) is a joint venture of the Max Planck Institute for the Structure and Dynamics of Matter, Deutsches Elektronen Synchrotron (DESY), the Universität Hamburg and the European XFEL GmbH.

The YBCO

By M Swami

Former student of CUTN (iMSc Physics).
His interests are supercounductors and its applications.

Abstract - This articles primary focus is on high temperature superconductivity nature of (Yttrium barium copper oxide) YBCO, its discovery has fulfilled current research needs, the parameters involved to understand the Pseudo gap Phase of this fabric. Comparison of Y: Ba: Cu = 1:2:3 and 3:5:8, preparation methods which involved in reflecting critical temperature of YBCO. The advance of the inquiry on the superconductivity .Why YBCO while we already have $HgBa_2Ca_2Cu_3O_{10,}$ which has a high critical temperature of 133K. Development of conductor based on HTSC, Power applications of this fabric.

I. INTRODUCTION

Superconductivity is a property of the certain materials, with the influence of some parameters, it loses complete resistance below a certain critical temperature. It happens in materials like ceramics, pure metals, alloys, etc. It was first discovered in mercury in 1911 when Kamerlingh Onnes cooled the material in liquid helium. So, suddenly it surprised everyone with its strange behaviour and then they tried checking the same property with Pb, Nb, NbN, Nb_3Sn, NbTi, NbAlGe, Nb_3Ge etc. in those days Nb-based compounds only have a quite high critical temperature. So, they mostly concentrated on Nb-based compounds.

In 1986 suddenly everything got changed, when J. Georg Bednorz and K. Alex Mller discovered a material, La_2CuO_4, with a critical temperature of 35K. The La_2CuO_4 compound is completely different from the materials which showed superconductivity in earlier days. It has a complex crystal structure made of several components, based on copper oxide units. This discovery earned Bednorz and Mller a Nobel Prize and was followed a year later by the discovery, by Paul Chu and colleagues, of another material, $YBa_2Cu_3O_7$ (often abbreviated to YBCO or 1-2-3 from the ratio of its metal atoms) which has a higher critical temperature of 92K. Which meant, it crossed the boiling point of liquid nitrogen. So, cooling problems were finally at an end, the research on this area became easy because liquid nitrogen is very cheap and we have enough nitrogen in the atmosphere to produce it.

II. THEORY AND RESEARCH

They (BCS) explained the formation of superconductivity based on the formation of electron pairs inside the lattice this is called Cooper pairs. When this pairing happens coulomb interaction gets modified and they start moving in pairs in the same direction and the total spin of the electrons is zero, because they both have opposite spins. BCS theory is based on the interaction of Phonon and its precise mechanism which is still a mystery.

What is known is that the composition of the copper-oxide materials has to be precisely controlled if superconductivity is to occur, Look at figure 1. $YBa_2Cu_3O_7$ can be regarded as being derived from semiconductor $YBa_2Cu_3O_6$ by doping with O_2 charge carriers formed by oxidation. However the crystal is not completely saturated with oxygen atoms, and there are a number of vacancies in the lattice. Thus the actual superconducting material is often written as $YBa_2Cu_3O_{7-d}$, where 'd' must be less than 0.7 if the material is to be superconducting. The reason for this is still not clear, but it is known that the vacancies occur only in certain places in the crystal, the copper oxide planes, and chains, giving rise to a peculiar oxidation state of the copper atoms, which somehow leads to the superconducting behaviour.

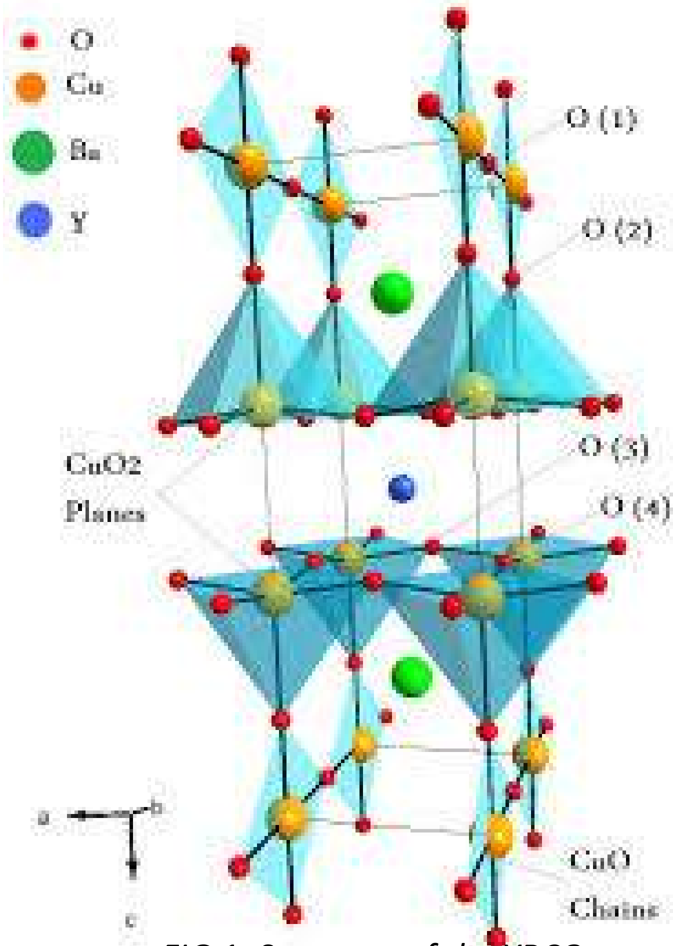


FIG 1: Structure of the YBCO

A. Latest theory

People at the University of Waterloo, Harvard and Perimeter Institutes have arrived at a new theory and explains the transition phase to superconductivity, or "pseudo gap" phase, which may be the final key to open the dark secrets of the material and major unsolved problems in the history of high temperature superconductivity.

One of the great Physicist at Hawthorn showed Harvard University Physicist Sachdev his latest experimental data on a superconducting material made of Copper and the elements Yttrium and Barium. The material, $YBa_2Cu_3O_{6+x}$, had a quite complicated temperature dependence. Sachdev had a theory, but, needed expert assistance with the complex set of calculations to make it a reality. Interactions are very large we need to take every single effect into account since it is a many body problem complexities of mathematics arrived. Physicists have turned their sights to the phase that comes just before superconductivity takes over: the mysterious "pseudo gap" phase.

The cuprate, $YBa_2Cu_3O_{6+x}$, is one of the few materials known to be superconductive at higher temperatures, but researchers around the planet can't achieve the superconductivity above -179 Degree Celsius. Not only the critical temperature of the material but, critical electrical density, critical magnetic density also contributes in superconductivity. So, these three parameters set a boundary to the phase of the superconductivity. A new study found that $YBa_2Cu_3O_{6+x}$oscillates between two quantum states during the Pseudo gap phase, one of which calls for the charge-density wave fluctuations. These periodic fluctuations in the dispersion of the electrical charges are what destabilize the superconducting state above the critical temperature. In one case the material is cooled to a lower place than the critical temperature, the potency of these fluctuations falls and the superconductivity state takes over.

In Figure 2 we can see the material in which we discovered superconductivity and in the next step of the research how Nb molecule takes the attention of researchers in those days due to its high critical temperature when we compared to other elements like Hg, Pb, etc. But, research was slowly progressing due to the problems of Helium, it's very difficult to produce liquid helium in those days and it's quite a high cost. In 1980s everything got changed, when one of the scientists discovered superconductivity in the ceramic material. As time progress critical temperature of the ceramic materials has increased. Now, we have achieved a high critical temperature of 133K in $HgBa_2Ca_2Cu_3O_{10}$. But, there is no much research progress in that material because it's highly toxic. So, YBCO is the promising material for future needs.

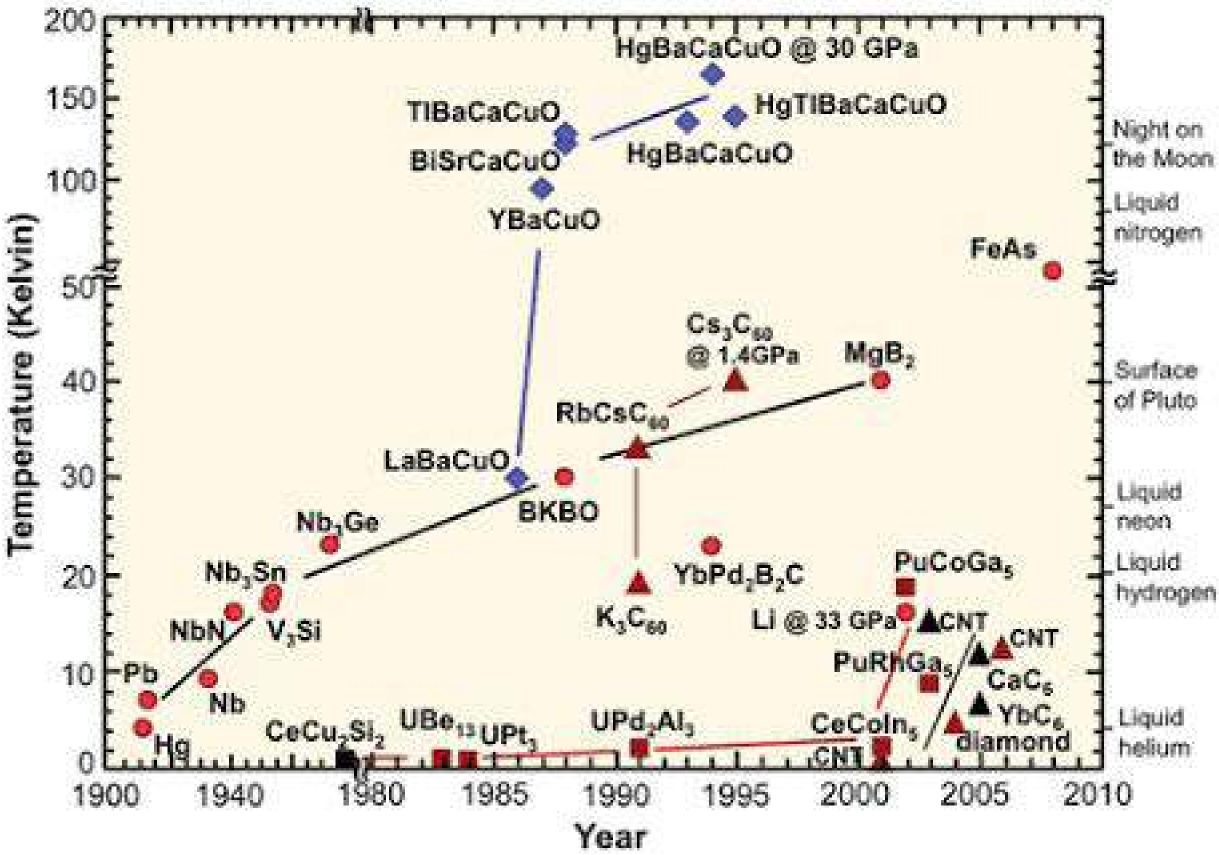


FIG 2:Schematic figure shows the progress of research on different materials and changes of critical temperature with respect to time.

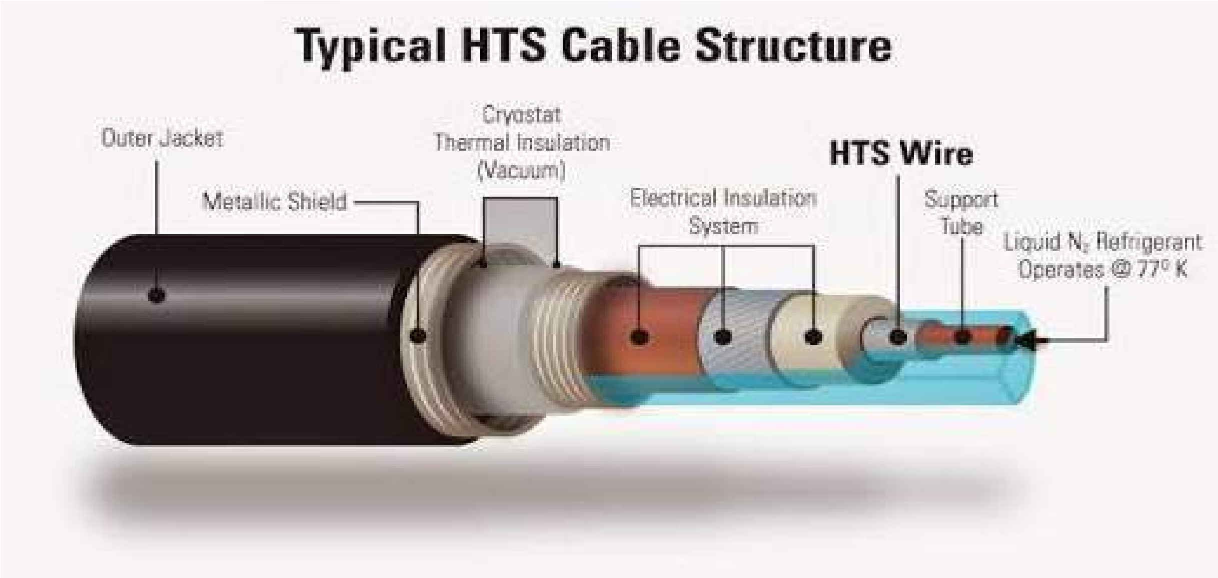


Figure 3 shows the Power transmission HTS cable configuration.

III. APPLICATIONS

The world-record magnets test coil was wound by Schenectady, N.Y. based Superpower with a well-known, high-temperature superconductor called yttrium barium copper oxide, or YBCO. Superpower develops superconductors such as YBCO and related technologies for the electric power industry. The magnet labs Applied Superconductivity Centre has worked with the company to determine the superconducting and mechanical properties of YBCO and other materials. This test demonstrates what we had long hoped that YBCO high-temperature super conductors being made now for electric utility applications also have great potential for high-magnetic-field technology, it seems likely that this conductor technology can be used to make all-superconducting magnets with fields that will soon exceed 30 tesla. This far exceeds the 22- to 23-tesla limit of all previous niobium-based superconducting magnets. (Niobium is the material used to build most superconducting magnets.) It also playing a great role in medical applications such as MRI etc.

IV. CONCLUSION

Presently, it became one of the fastest growing research fields across the globe, improving synthesize methods can make a lot of difference in current density, magnetic density and critical temperature of the material. At the same time, theoretical solutions are presented that could improve the structure of the material which can implement in pseudo gap phase. There are companies like STI, AMSC generating the ideas, technologies and solutions that meet the worlds' demand for superconductivity. These companies have produced superconductive cables just like the copper wires in our houses for transmission of power. And YBCO material producing high magnetic fields ever possible. So, this is the future material which solves all the energy problems.

BLACK HOLES: POSSIBLE FATE

By Rohan Ch. Das
iMSc Physcis 1st year

For the human race it was always very fascinating to look at the night sky. Our inquisitiveness increased with the twinkling of distant stars, high up in the sky. The present universe in which we are now, originates from a singularity and most probably converge down to singularity again says a theory. Readers, I am a student of 1ST YEAR IMSc. Physics. I don't have deep knowledge on the internal theories going on about the black holes like researchers and scientists. But, at the same time, I have the thirst to know and learn about what are black holes and what they do, so I went ahead and learnt about them a little and here I am to share about it to you all.

A black hole is a region of space-time exhibiting such strong gravitational effects that nothing—not even particles and electromagnetic radiation such as light—can escape from inside it. The theory of general relativity predicts that a sufficiently compact mass can deform space-time to form a black hole. The boundary of the region from which no escape is possible is called the event horizon. Although crossing the event horizon has enormous effect on the fate of the object crossing it appears, to have no locally detectable features. In many ways a black hole acts like an ideal black body, as it reflects no light. Moreover, quantum field theory in curved space-time predicts that event horizons emit Hawking radiation, with the same spectrum as a black body of a temperature inversely proportional to its mass. This temperature is in the order of billionths of a kelvin for black holes of stellar mass, making it essentially impossible to observe.

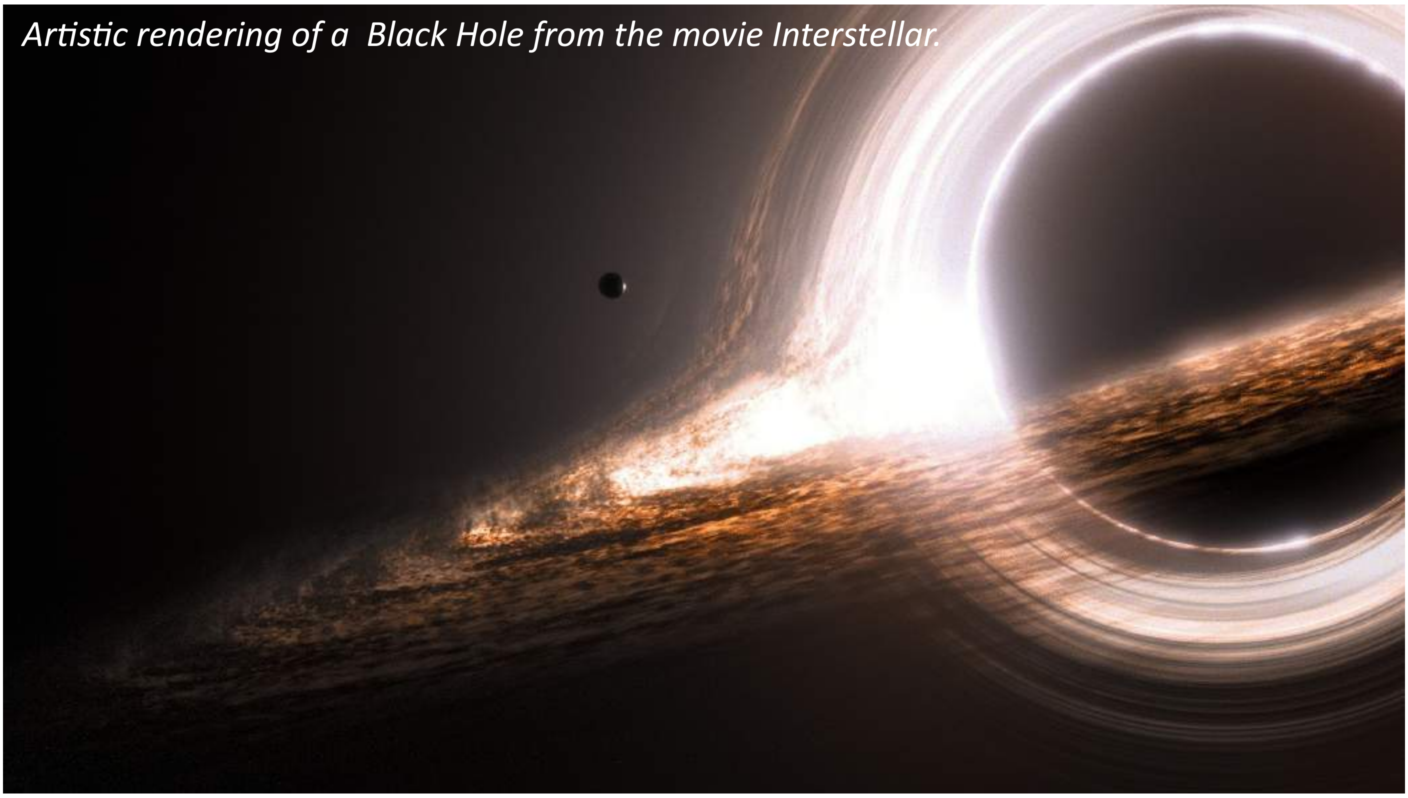
Objects whose gravitational fields are too strong for light to escape were first considered in the 18th century by John Michell and Pierre-Simon Laplace. The first modern solution of general relativity that would characterize a black hole was found by Karl Schwarzschild in 1916, although its interpretation as a region of space from which nothing can escape was first published by David Finkelstein in 1958. Black holes were long considered a mathematical curiosity; it was during the 1960s that theoretical work showed they were a generic prediction of general relativity. The discovery of neutron stars sparked interest in gravitationally collapsed compact objects as a possible astrophysical reality.

Black holes of stellar mass are expected to form when very massive stars collapse at the end of their life cycle. After a black hole has formed, it can continue to grow by absorbing mass from its surroundings. By absorbing other stars and merging with other black holes, super-massive black holes of millions of solar masses ($M_{\odot}$) may form. There is general consensus that super-massive black holes exist in the centr of most galaxies.

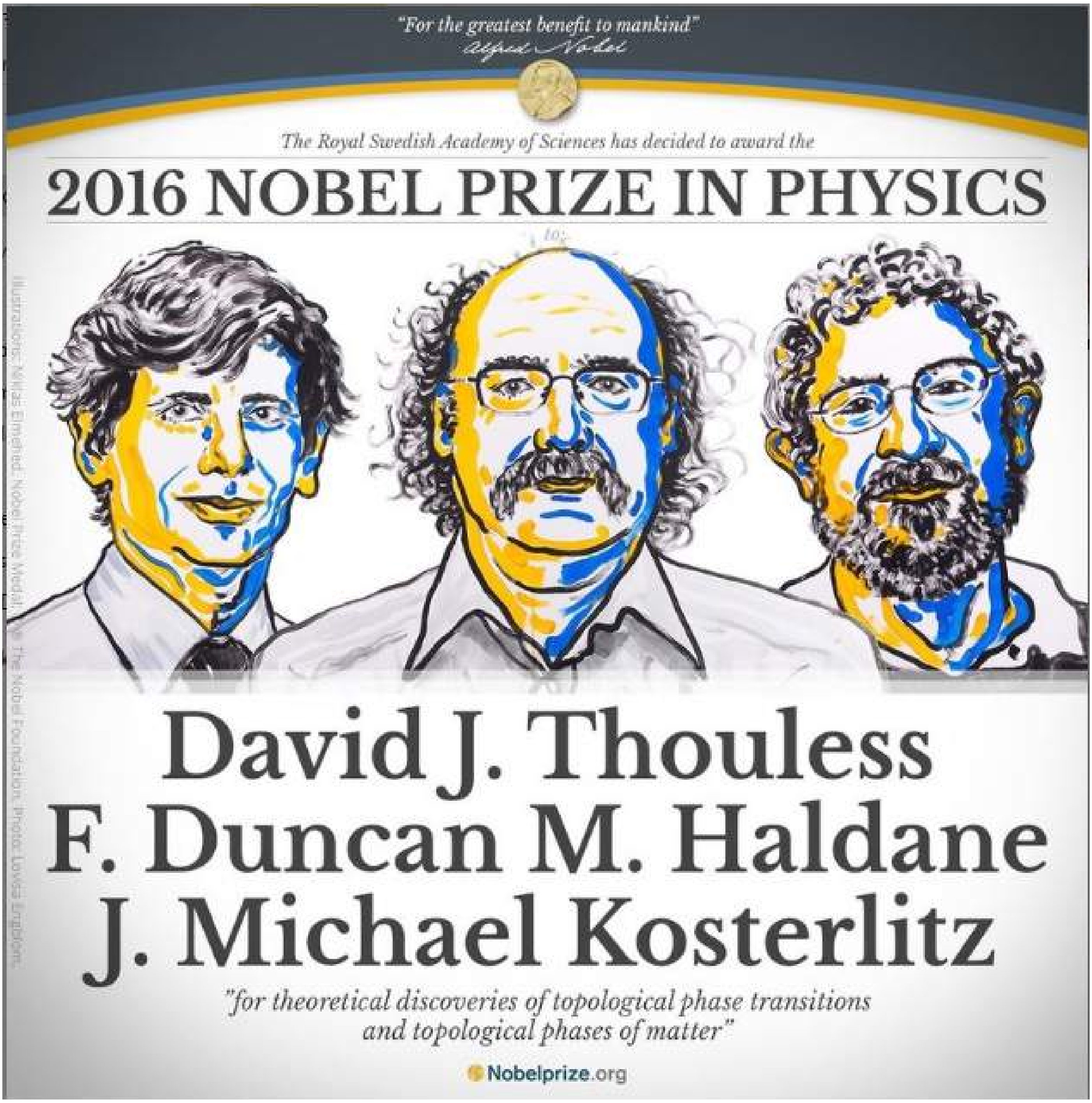
Despite its invisible interior, the presence of a black hole can be inferred through its interaction with other matter and with electromagnetic radiation such as visible light. Matter that falls onto a black hole can form an external accretion disk heated by friction, forming some of the brightest objects in the universe. If there are other stars orbiting a black hole, their orbits can be used to determine the black hole's mass and location. Such observations can be used to exclude possible alternatives such as neutron stars. In this way, astronomers have identified numerous stellar black hole candidates in binary systems, and established that the radio source known as Sagittarius A, at the core of our own Milky Way galaxy, contains a super-massive black hole of about 4.3 million solar masses.

On 11 February 2016, the LIGO collaboration announced the first observation of gravitational waves; because these waves were generated from a black hole merger it was the first ever direct detection of a binary black hole merger. On 15 June 2016, a second detection of a gravitational wave event from colliding black holes was announced

Thus, we can say that slowly and steadily, the black holes might be collapsing every object of the universe and bring it down to a singularity again. That singularity might repeat the cycle again and again.



Artistic rendering of a Black Hole from the movie Interstellar.



Nobel Prize for this year goes to three men, who in their work in the 1970s and 1980s, explained the very weird, strange thing that happens to matter when someone squishes it down to a flat plane, or cools it down to near absolute zero. Half of the prize, goes to David Thouless of the University of Washington, and the other half is to be split between Duncan Haldane of Princeton University and J. Michael Kosterlitz of Brown.

"It has combined beautiful mathematics and profound physics insights, and achieved unexpected results that has been confirmed by experiments," said Thors Hans Hansson, a Nobel committee member, at the Nobel announcement.

Now, what exactly did they prove??

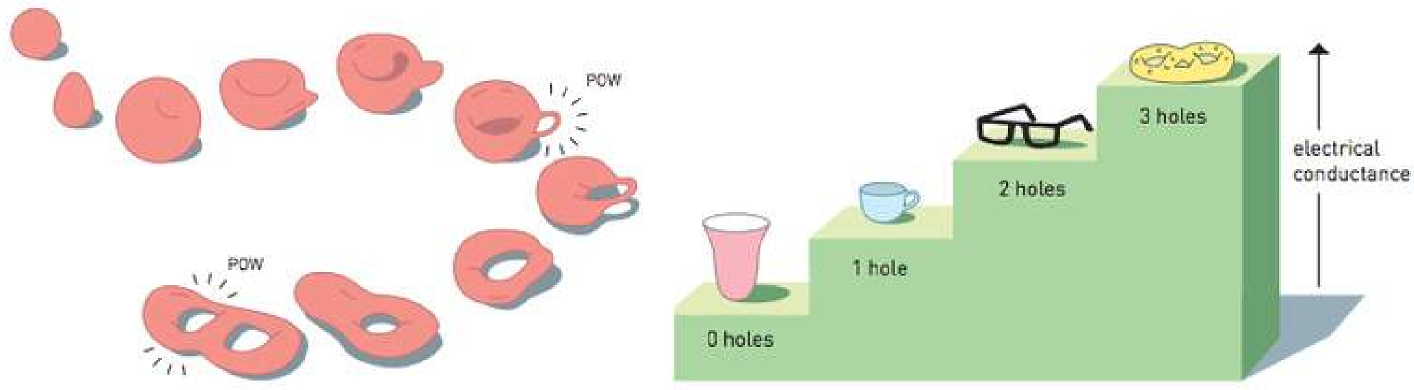


Fig 3. Topology. This branch of mathematics is interested in properties that change step-wise, like the number of holes in the above objects. Topology was the key to the Nobel Laureates' discoveries, and it explains why electrical conductivity inside thin layers changes in integer steps.

They showed the fremd properties of "Matter" at cold or condensed states by using the mathematics of Topology. Topology is a branch of math that deals with the properties which are preserved when they are stretched, deformed, or twisted. During the prize announcement, Mr Hanson brought along a cinnamon bun, a bagel, and a pretzel to explain it. He took the three things and proceeded by counting the number of holes in it, i.e, a bun has no holes, a bagel has one, and a pretzel has two. Also there will be no half holes in these and thus when we stretch or twist or deform it, the number of holes in these three objects would remain the same irrespective of twisting or stretching.

These three guys were able to illuminate mysteries like how helium or super-cold films change their phase of matter, and how the properties of those phase transitions change again accordingly. Beyond its Theory, it has also persuaded a lot of scientist to develop new materials with novel properties. One very good example would be the topological insulators, which conduct electricity solely on their surface. Although this has not been made for any commercial use as of yet.

Now with these ongoing researches, scientists are very much excited about the possibilities of using these materials in quantum computing and other yet-to-be discovered applications. One of these insulators, called 'Stanene', which is basically a one-atom thick layer of tin has the ability to conduct electricity at high temperatures with little resistance. Scientists are now even hoping that one day this Stanene could perhaps replace the year-old copper components which are being used explicitly in the computers today.

Arunav D.
iMSc Physics
4th year

Computer Simulations For A Coin Toss Experiment

By P Sri Harsha and Athul K P
iMSc Physics 4th year

A simple and basic discussion on Probability and the theories that validate it, combined with Computer Simulations and their importance in solving problems in physics.
keywords: Probability, Simulation, coin toss, Random numbers
Problem was first discussed in the course Statistical Mechanics by Dr. M. Ponmurugan.

INTRODUCTION

We say that the probability of heads or tails for tossing a coin is 0.5, but if we toss a coin twice do we get head once and tail, the answer is not always that so why do we say the probability is 0.5 and where did we go wrong. Right from the introduction of the topic of Probability we have been hearing that the chance of an event occurring is given by the formula:

$$\text{Probability} = \frac{\text{No of favourable events}}{\text{Total number of events}}$$

This does not end here as we are heading to a more technological dependent life most of our day to day events are planned and executed through the knowledge of probability, and the dependence start right from the weather report or stock market performances to the occurrence of astronomical events, so the concept of probability is very important and we all know it, but how can we be sure that it always works and does it really work the way as we are told.

In a deterministic universe, based on Newtonian concepts, there would be no probability if all conditions were known. Physicists face a situation in kinetic theory of gases, where the system, while deterministic in principle, is so complex (with the number of molecules typically the order of magnitude of Avogadro Number) that only a statistical description of its properties is feasible.

Probability theory is required to describe quantum phenomena. A revolutionary discovery of early 20th century physics was the random character of all physical processes that occur at sub-atomic scales and are governed by the laws of quantum mechanics. The objective wave function evolves deterministically but, according to the Copenhagen interpretation, it deals with probabilities of observing, the outcome being explained by a wave function collapse when an observation is made. Albert Einstein famously remarked in a letter to Max Born: "I am convinced that God does not play dice". Like Einstein, Erwin Schrödinger, who discovered the wave function and believed quantum mechanics is a statistical approximation of an underlying deterministic reality.

Being students of science and inquisitive of nature lets take simple example of tossing a coin and see if the theory of probability actually works the way it is supposed to. As we are studying Physics we are inherently lazy to toss a coin and record its results is we will be using computer simulations to pander our laziness, we will conduct the experiment virtually and see for ourselves if the theory of probability really holds.

Computer Simulations

Computer simulation is a simulation run on a single or a network of computers to reproduce the behaviour of a system. Computer simulation developed hand in hand with the rapid growth of computer following its first large scale deployment during the Manhattan project in world war II to model the process of nuclear detonation, it was a simulation involving 12 hard spears using computer algorithms.

There are many types of computer simulations; their common feature is the attempt to generate a sample of representative scenarios for a model

```
#include <stdlib.h>
#include <iostream.h>
#include <time.h>
int main()
{
    int number,heads=0, tails=0,head[1000],tail[1000];
    float headsum=0,tailsum=0;
    int trails=0,times=0;
    cout<<"how many times do you want to toss the coin:";
    cin>>trails;
    cout<<"how many times do you want to repeat the experiment:";
    cin>>times;
    srand(time(NULL));
for(int j=0;j<times;j++)
   {
     for(int i=0;i<trails;i++)
        {
         number = rand() %10;
         if (number%2==0)
            {
              heads++; //This is head
            }
         if (number%2==1)
            {
              tails++; //This is tail
             }
         }
     head[j]=heads;
     tail[j]=tails;
     headsum=headsum+head[j];
     tailsum=tailsum+tail[j];
     heads=0;
     tails=0;
    }
cout<<"the avarage of probability for all the experiments are:"<<endl;
cout<<"average of probability for heads are:"<<headsum/(trails*times)<<endl;
cout<<"average of probability for tails are:"<<tailsum/(times*trails);
cin>>times;
return 0;
}
```

C++ Program for tossing a coin and to dispay the average of probability.

in which a complete enumeration of all possible sates of a model would be prohibitive or impossible.

In the simulation which we are about to see we will be using Monte Carlo method, Monte Carlo methods are a broad class of computational algorithms that relay on the repeated random sampling to obtain numerical results, their essential idea is using randomness to solve problems that might be deterministic in principle.

Through the course of our experiment we will be using various programming languages like C++ , Mathematica , Python for the reason that they have their own advantages and for a easier understanding of the reader. In the below subsections we will first see what mathematics has to say about probability in a relative rigour hand in hand with relating computer simulations.

Computer Simulation with a Mathematical Digress

It is not possible to predict precisely the results of random events. However, if a sequence of individual events, such as coin flipping or the roll of dice, is influenced by other factors, such as friction, it will exhibit certain patterns, which can be studied and predicted.

C++ program:

Two representative mathematical results describing such patterns are the law of large numbers and the central limit theorem. As a mathematical foundation for statistics, probability theory is essential to many human activities that involve quantitative analysis of large sets of data. Methods of probability theory also apply to descriptions of complex systems given only partial knowledge of their state, as in statistical mechanics. A great discovery of twentieth century physics was the probabilistic nature of physical phenomena at atomic scales, described in quantum mechanics.

To simulate a random event we will use a random number generator. (See appendix) Here below we will see a C++ program which simulates a coin toss where the value 1 is assigned to head and the value 0 to tail. The program can toss a coin for a user specified number times and also repeats the entire experiment if the user feels to do so. Output of the program for a few trail inputs is given below:

```
how many times do you want to toss the coin:10
how many times do you want to repeat the experiment:10
the avarage of probability for all the experiments are:
average of probability for heads are:0.55
average of probability for tails are:0.45


how many times do you want to toss the coin:100
how many times do you want to repeat the experiment:100
the avarage of probability for all the experiments are:
average of probability for heads are:0.572
average of probability for tails are:0.428


how many times do you want to toss the coin:100
how many times do you want to repeat the experiment:500
the avarage of probability for all the experiments are:
average of probability for heads are:0.568
average of probability for tails are:0.432


how many times do you want to toss the coin:1000
how many times do you want to repeat the experiment:500
the avarage of probability for all the experiments are:
average of probability for heads are:0.496
average of probability for tails are:0.504
```

C++ program output

In the above simulation we use a random function to generate a head or a tail for the number of times the user needs and then calculate the probability by simple mathematical formula. In output shown above we can see the average of probability for the given number of times and we can see that the probability is close to the theoretical value but is not exactly the same, this means that there is something wrong and here we will use two important theorems in probability theory to answer the results obtained.

Law of large numbers:

In probability theory, the law of large numbers is a theorem that describes the result of performing the same experiment a large number of times. According to it, the average of the results obtained from a large number of trials should be close to the expected value, and will tend to become closer as more trials are performed.

This is important because it ”guarantees” stable long-term results for the averages of some random events. It is important to remember that the Law of Large Numbers only applies when a large number of observations are considered. There is no principle that says that a small number of observations will coincide with the expected value of the event.

Central Limit theorem

In probability theory, the central limit theorem states that, given certain conditions, the arithmetic mean of a sufficiently large number of iterates of independent random variables, each with a well-defined expected value and finite variance, will be approximately normally distributed.

What this means is that if a sample has a large number of observations where each observation is obtained randomly, and that the arithmetic average of the obtain observations are calculated and if this process is performed many times,

```
Manipulate[
 SeedRandom[];
 G = Array[0 &, r];
 Do[
  y = Accumulate[RandomInteger[BernoulliDistribution[p], n]] / Range[n];
  G[[i]] = ListPlot[{x, y} // Transpose, Joined → True, Frame → True, Axes → False,
        PlotRange → {{0, Log[10, n]}, {0, 1}},
    FrameTicks → {{{Log[10, 3], "3"}, {Log[10, 20], "20"}, {Log[10, 100], "100"},
                {Log[10, 1000], "1000"}, {Log[10, 10000], "10000"}},
                {0.25, 0.5, 0.75, 1.0}, None, None}, FrameLabel →
                {"Number of tosses", "Proportion of heads"},
    PlotStyle → Thin, Epilog → {Black, Opacity[0.8], Thickness[Small],
      Line[{{0, p}, {Log[10, n], p}}]}, ImageSize → Full], {i, 1, r}];
 Show[G],
 {{p, 0.5, "probability of heads ="}, Appearance → "Closed"},
 {{r, 1, "repetitions"}, 1, MaxRep, 1, Appearance → "Labeled"},
 TrackedSymbols :→ {r, p},
 Initialization :→ (
   n = 10000;
   x = Log[ 10, Range[n]];
   MaxRep = 20;
  )]
```

Mathematica program For random tossing of a coin and then to plot the results

according to central limit theorem the calculated average value will be distributed in a normal distribution or also called as a bell curve.

Simply put if we flip a coin many times the probability of getting a given number of heads should follow a normal curve, which means that there are equal heads and tails in the total number of flips. Now let us conform if the discrepancies found in the above C++ program can be eliminated if we take a set of large number of trails as dictated by Law of Large Numbers and Central Limit Theorem, with a Mathematica program.

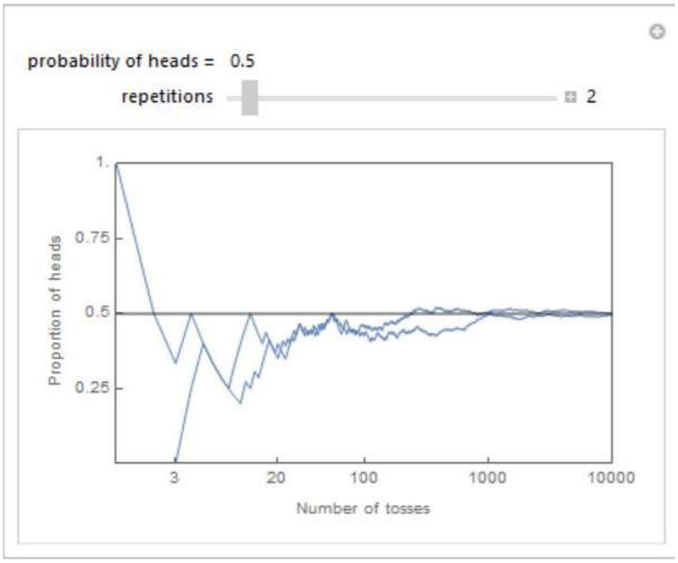
Mathematica Program:

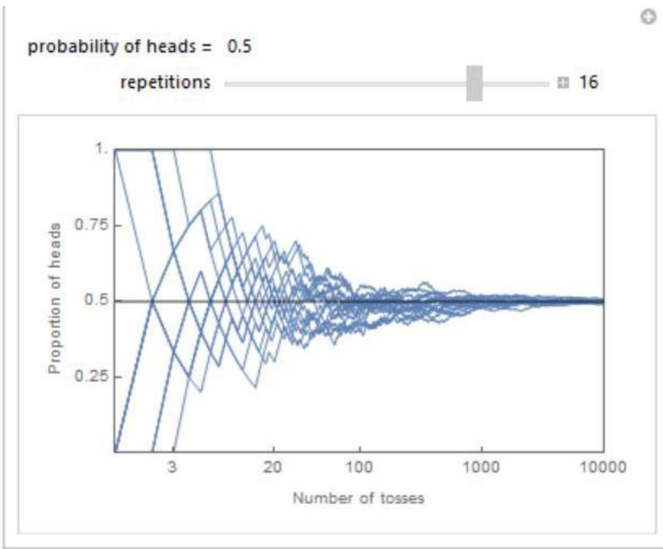
The below program will again simulate a random tossing of a coin and will plot the results with data points of tossing at 3, 20, 100, 1000 and 10000 times, the experiment can also be repeated to maximum of 20 times and the combined result of all the repetitions can be seen simultaneously.

Here we again use a random number generator which generates random number 1 or 0; Using the concept of Bernoulli Distribution which is the probability distribution of a random number with success probability 1 and failure probability 0. Here we are using this to simulate a coin toss where 1 represents a head and 0 a tail.

Through the output given in the page below one observe that as the number of trials are increasing we can see that the experimental value of the probability is getting closer and closer to the theoretical value. So we can conclude that Law of large numbers and Central Limit theorem hold and will give us stable results over a large number of trials as they are supposed to.

We have seen the simplicity of C++ and the Power of Mathematica to solve complex functions and give condensed and easy to understand results, Now let us use another programming language- python which is famous for its simplicity and object oriented scripting where C++ is object oriented compiling, along with many other added advantages like allocation of memory by the interpreter, huge standard library.





Mathematica program output

Python program to simulate coin toss and plot standard deviation Vs number of trail:

.

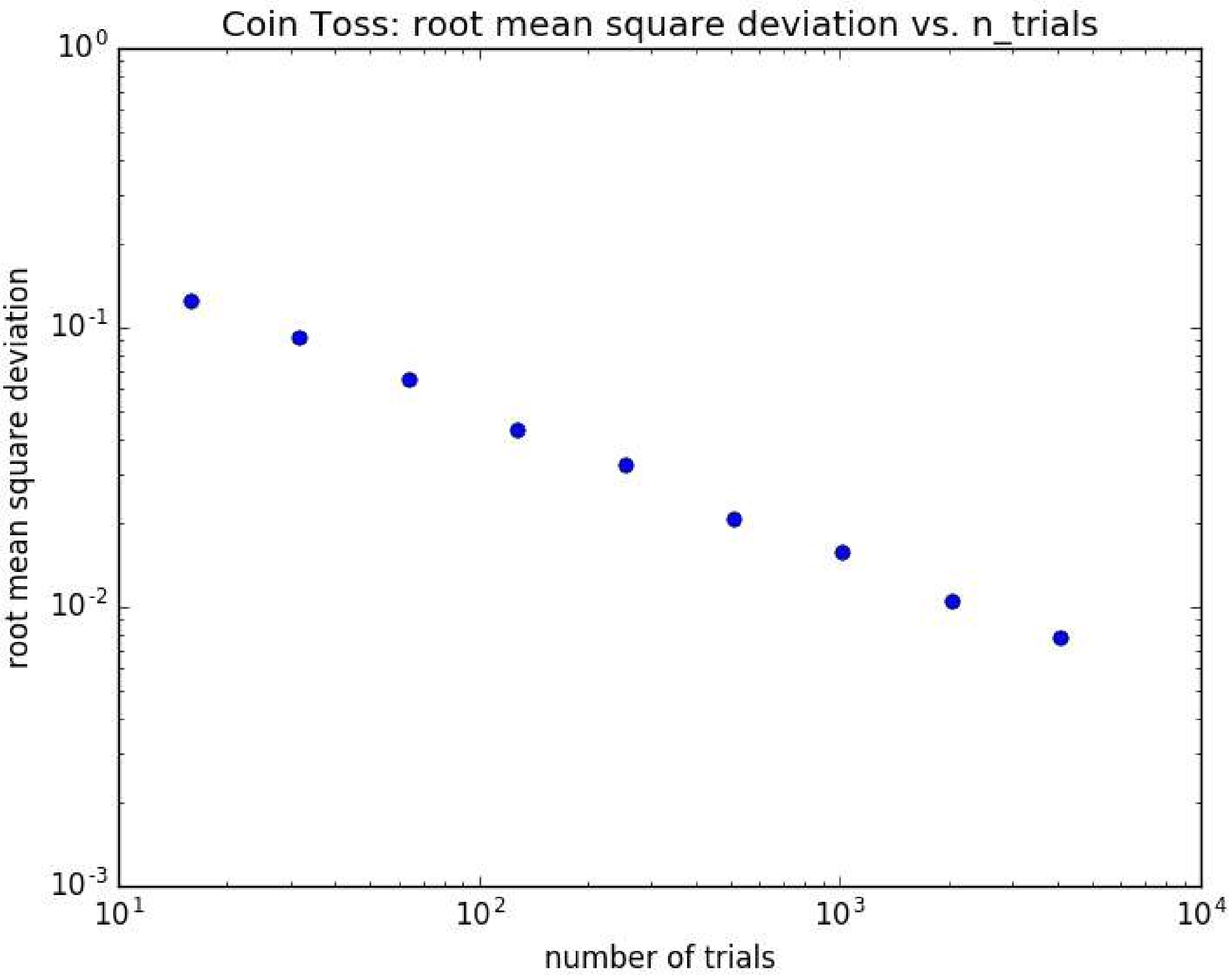
Using Python we will again repeat the experiment of tossing a coin but this time the output is not a numerical or a graphical representation of the solution but the error in the solution for different number of trails. This statistical approach to the problem by finding out the error in the solution other than directly finding out the solution, will give us better understanding of the experiment.

Since the heads and tails are equiprobable, it's easier to consider only one of heads or tails. So let's just count the heads from now onwards. The given Python program contains a function to generate number of heads for given number of trail. Once we know the number of heads, we can easily find out probability of heads. Later experiment is repeated several hundred times and by using all those values the standard deviation in the probability of heads is found.

The experiment is repeated for several number of trails and at last a relation between standard deviation is plotted against number of trails. From the graph below which plots the standard deviation VS number of trails, we can conclude that standard deviation goes to zero as number of trails is going to infinity. That is, as trials tend to infinity probability of heads or probability of tails will tend to be closer and closer to the theoretical value of 0.5 .

```
import random, math, pylab

def coin(N):
    n_hits = 0
    for t in range(N):
        r = random.choice([0, 1])
        if r == 1:
            n_hits += 1
    return n_hits


n_runs = 500
n_trials_list = []
sigmasqs = []
for poweroftwo in range(4, 13):
    n_trials = 2 ** poweroftwo
    sigmasq = 0.0

    for run in range(n_runs):
        p_est = coin(n_trials)/ float(n_trials)
        sigmasq += (p_est - 0.5) ** 2

    sigmasqs.append(math.sqrt(sigmasq/(n_runs)))
    n_trials_list.append(n_trials)

pylab.plot(n_trials_list, sigmasqs, 'o')
pylab.xscale('log')
pylab.yscale('log')
pylab.xlabel('number of trials')
pylab.ylabel('root mean square deviation')
pylab.title('Coin Toss: root mean square deviation vs. n_trials')
pylab.savefig('coin_toss_rms_deviation.png')
pylab.show()
```

Python program For tossing of a coin and then to plot the standard deviation



Appendix:

Random Numbers:

Random numbers are useful for a variety of purposes, such as generating data encryption keys, simulating and modelling complex phenomena and for selecting random samples from larger data sets. They have also been used aesthetically, for example in literature and music, and are of course ever popular for games and gambling. When discussing single numbers, a random number is one that is drawn from a set of possible values, each of which is equally probable, i.e., a uniform distribution. When discussing a sequence of random numbers, each number drawn must be statistically independent of the others.

With the advent of computers, programmers recognized the need for a means of introducing randomness into a computer program. However, surprising as it may seem, it is difficult to get a computer to do something by chance. A computer follows its instructions blindly and is therefore completely predictable. There are two main approaches to generating random numbers using a computer: Pseudo Random Number Generators (PRNGs) and True Random Number Generators (TRNGs).

Pseudo-Random Number Generators:

As the word 'pseudo suggests, pseudo-random numbers are not random in the way you might expect, at least not if you're used to dice rolls or lottery tickets. Essentially, PRNGs are algorithms that use mathematical formulae or simply pre calculated tables to produce sequences of numbers that appear random. A good example of a PRNG is the linear congruential method. A good deal of research has gone into pseudo-random number theory, and modern algorithms for generating pseudo-random numbers are so good that the numbers look exactly like they were really random.

PRNGs are typically periodic, which means that the sequence will eventually repeat itself. While periodicity is hardly ever a desirable characteristic, modern PRNGs have a period that is so long that it can be ignored for most practical purposes.

True Random Number Generators

In comparison with PRNGs, TRNGs extract randomness from physical phenomena and introduce it into a computer. You can imagine this as a die connected to a computer, but typically people use a physical phenomenon that is easier to connect to a computer than a die is. The physical phenomenon can be very simple, like the little variations in somebody's mouse movements or in the amount of time between keystrokes. In practice, however, you have to be careful about which source you choose. A really good physical phenomenon to use is atmospheric noise, which is quite easy to pick up with a normal radio.

The characteristics of TRNGs are quite different from PRNGs. First, TRNGs are generally rather inefficient compared to PRNGs, taking considerably longer time to produce numbers. They are also non-deterministic, meaning that a given sequence of numbers cannot be reproduced, although the same sequence may of course occur several times by chance. Efficiency is a nice characteristic if your application needs many numbers, and determinism is handy if you need to replay the same sequence of numbers again at a later stage. TRNGs have no period.

References:

· Wikipedia web pages for probability theory, Law of large numbers, Central Limit Theorem

· Concepts of C++ programming from c++ programming language(fourth edition) by "Bjarne Stroustrup"

· Mathematica coding from Mathematica software Documentation

· Mathematica code is written by taking references and replicating code modules from: "Simulated Coin Tossing Experiments and the Law of Large Numbers" from the Wolfram Demonstrations Project http://demonstrations.wolfram.com/SimulatedCoinTossingExperimentsAndTheLawOfLargeNumbers/

· Concepts on Random Number generators from web-pages of Random.org

· Concepts on python programming from the webpages of Python.org

Acknowledgements:

· We thank Dr. M.Ponmurugan for his constant guidance, suggestions and for helping us gain a conceptual clarity

· We thank our class mates from the department of physics for giving tips, ideas and helping us complete this article in time.

Department Tour

By Batch 2012-17

iMSc Physics
5th year

A well awaited dream of an academic tour for the final year batch of IMSc Physics (2017), finally came true on 16th October 2016.

We were a group of 22 students and three faculty members, Dr. Venkat Saravan, Dr. Vijayalakshmi and Mr. Sultan Ibrahim, and started our journey on time.

The train to Dindigul was boarded from Mayiladudurai. After four hours of chatting, games and snapshots, we reached Dindigul around 4.00 pm where Dr. Arunkumar joined us. In a little coffee shop there we had our evening beverage and freshened up for the next round of the trip.

Everyone hopped into the private bus arranged by the organizers and started off to Kodaikanal. In between we stopped a while at the sides of NH4 to marvel at the black carpet rolled out in front of us with its ornamental white strips .The setting sun gave the whole set a classy orange backdrop. It's almost a crime these days not to take snaps, especially selfies at places like this and nope, we didn't dare to break the rule! After a good ten minutes there, we continued on with our journey.

A little after dark fell and we had started climbing up the windy roads to Kodaikanal. We stopped to enjoy the waterfalls of Silver Valley. But the beauty was marred. The water seemed to be struggling to gush out of the maze of mess humans had made.

There was a lavish spread of pollutants of all kind. The mystery of people who want to bask in the spirit of Mother Nature destroying its very essence hung in the air like a sad folklore.

We reached Kodai around 8.00 pm and our stay was arranged at the youth hostel. There we checked into our dorms, got freshened up and came out to be received by a delicious homemade meal brought by Dr. Arunkumar. Sitting down in the courtyard, all of us enjoyed the treat of warm food and the cool mist.

The next day we set off to the Indian Institute of Astrophysics, where we explored a little about the various fields and aspects of astrophysics. A museum set up there explaining the ongoing research and instrumentations in the field was really enlightening.

Being in a place so beautiful a little sightseeing was due and we began with the famous Moir Point and later visited the

Green valley point. At each of these places one could see the magnificence of the ranges through the heavenly mist which floated around. Guna Caves are one of the places which overwhelmed us with the grandeur of Nature. There, one could see the deep dark vents in the ground where the two hills are joined together.

The Kodaikanal Lake was lively and crowded with people from everywhere. A few of us were in the lake in pedal boats steering through the calm, cold water, and the rest cycled around the lake. There were shops surrounding the lake stocked with the famous homemade chocolates and various artifacts. After a good few hours, we returned to the hostel.

Later that night, we all took off to a cottage where we had a campfire set up. After a while of dancing around to the beats off the boom box, we settled down for a delicious bar-be-cue dinner prepared by the gifted culinary team among us.

The following morning we decided to visit the famous temple of Kurinji. The whole place was soaked in serenity and an inexplicable kind of quietness. From the edge of the temple one could see the ranges where Palani temple held its head high.

Later we visited the Croakers Walk, where we were to walk downhill on a pavement close to the edge where we enjoyed the vast green beauty which spanned across us. (Well, selfies were inevitable with a background this marvelous!!). And after a short visit to The Bryant Park we started our journey back.

We reached Dindigul around 8.30 and even after having a long dinner, we had a lot of time to kill before we caught the bus back to Tiruvarur and a movie seemed like the best plan. After three hours of action, drama and music we got into the bus for last and final lap.

Finally, on the fourth day, when we got down at Tiruvarur, early in the morning, our bags and minds were heavier with all the souvenirs from the trip.

GAUGE TRANSFORMATION

By P Sri Harsha
iMSc Physics
4th year

Introduction:

To get a basic idea of what is gauge transformation, first let us consider a basic scenario where I am dropping a ball of mass M from a roof top and let the height of the building be X, now from basic physics, I can say that the potential energy of the ball is $V = MgX$ with respect to ground and I know that the force on the ball is nothing but the derivative of the potential energy:

$$F = -\frac{\partial V}{\partial X} \tag{1}$$

$$F = -\frac{\partial (MgX)}{\partial X} \tag{2}$$

and we get the following equation of motion:

$$F = -Mg \tag{3}$$

Now let us go to another building which is much higher then the first one and here my potential with respect to the ground changes and I can write the potential energy of the ball as $V = MgX + V_o$ where V_o is a excess potential of the new building(which is constant) and now again if I try to find the equation of motion, I see that it remains unchanged as shown below:

$$F = -\frac{\partial V}{\partial X} \tag{4}$$

$$F = -\frac{\partial (MgX + V_o)}{\partial X} \tag{5}$$

$$F = -\frac{\partial (MgX)}{\partial X} + \frac{\partial V_o}{\partial X} \tag{6}$$

$$F = -Mg \tag{7}$$

From the above illustration we can conclude that even though the potential changed, equation of motion remained constant in both the cases and this captures the basic idea of gauge invariance.

Here the quantity V_o is our Gauge and the choice of coordinate system system is Gauge freedom. So, now Gauge invariance simply means the physics and equation of motion of the system remains unchanged under application of a select family of Gauges, it will be particularly useful when dealing with complicated problems in physics, in difficult situations when dealing with complex equations gauge transformations will come to our rescue by simplifying our work.

Formulation of potential:

Before I head all out into gauge transformations let us first look at the formulation of potentials. In electrostatics $\nabla \times E = 0$ which allowed me to write E as a negative gradient of potential: $E = -\nabla V$. But this is not possible in electrodynamics as curl of E is -$\frac{\partial B}{\partial t}$.

So there is a need to introduce some new variables that will remove the inconsistency in the Maxwell's equations for Electro-statics and Electro-dynamics which I will try to overcome using gauge transformations in the following subsections.

Gauge transformations in Electromagnetic theory:

Let me take a magnetic field B and I can say that

$$B = \nabla \times A \tag{8}$$

where A is a vector field. Now I will apply my Gauge transformation here and my Gauge in this case is the gradient of some scalar field λ .

$$A \rightarrow A + \nabla\lambda \tag{9}$$

Now let me plug this back in to my original expression for Magnetic field:

$$B = \nabla \times (A + \nabla\lambda) \tag{10}$$

Now I will use the identity that the curl of a gradient is zero,

$$\nabla \times (\nabla\lambda) = 0 \tag{11}$$

so I can write equation (10) as:

$$B = \nabla \times A + \nabla \times (\nabla\lambda) \tag{12}$$

$$B = \nabla \times A \tag{13}$$

so the magnetic field remains same under this family of gauge choices. now let us look at the electric field which is given as follows:

$$E = -\nabla V - \frac{\partial A}{\partial t} \tag{14}$$

where V is the scalar potential and A is the vector potential. Now I will apply gauge transformations:

$$A \rightarrow A + \nabla\lambda \tag{15}$$

$$V \rightarrow V - \frac{\partial \lambda}{\partial t} \tag{16}$$

Plugging these back into my original equation (14):

$$E = -\nabla(V - \frac{\partial \lambda}{\partial t}) - \frac{\partial(A + \nabla\lambda)}{\partial t} \tag{17}$$

$$E = -\nabla V + \nabla\frac{\partial \lambda}{\partial t} - \frac{\partial A}{\partial t} - \frac{\partial \nabla\lambda}{\partial t} \tag{18}$$

Which again gives back:

$$E = -\nabla V - \frac{\partial A}{\partial t} \tag{19}$$

from this we can conclude that for any scalar function $\lambda(r,t)$ we can add $\nabla\lambda$ to A, if we are substracting $\frac{\partial \lambda}{\partial t}$ from V. this will not effect **E** and **B**, and the changes in V and A are called as gauge transformations.

Below we will discuss about Coulomb and Lorenz gauge in brief. Before we head there let us look this general solution of Maxwell equations:

$$B = \nabla \times A \tag{20}$$

Using this in Faraday's law we get:

$$\nabla \times E = -\frac{\partial}{\partial t}(\nabla \times A) \tag{21}$$

up on rewriting we can see that curl of $E + \frac{\partial A}{\partial t}$ vanishes, so I should be able to write it as a gradient of a scalar.

$$E + \frac{\partial A}{\partial t} = -\nabla V \tag{22}$$

can be further simplified to

$$E = -\nabla V - \frac{\partial A}{\partial t} \tag{23}$$

Now using equations (20) and (23) we can full fill two
Maxwell's equations

$$\nabla . B = 0 \tag{24}$$

and

$$\nabla \times E = -\frac{\partial B}{\partial t} \tag{25}$$

but both Faraday and ampere law will take on an a complicated form below which could be rather difficult to solve:

$$\nabla^2 V + \frac{\partial}{\partial t}(\nabla . A) = -\frac{\rho}{\epsilon_o} \tag{26}$$

and

$$(\nabla^2 A - \mu_o\epsilon_o\frac{\partial^2 A}{\partial t^2}) - \nabla(\nabla . A + \mu_o\epsilon_o\frac{\partial V}{\partial t}) = -\mu_o J \tag{27}$$

Now we I will use different gauge transformations to simplify equations (26) and (27).

Coulomb Gauge:

In coulomb gauge we pick:

$$\nabla . A = 0 \tag{28}$$

now using this in equation (26) we can simplify it

$$\nabla^2 V = -\frac{\rho}{\epsilon_0} \tag{29}$$

which is nothing but Poisson's equation. and the equation (27) will be

$$\nabla^2 A - \mu_o\epsilon_o\frac{\partial^2 A}{\partial t^2} = -\mu_o J + \mu_o\epsilon_o\nabla(\frac{\partial V}{\partial t}) \tag{30}$$

from these above equations we can say that the advantage of coulomb gauge is that scalar potential is particularly simple and **A** is difficult to calculate.

Lorenz Gauge:

In Lorenz gauge we use:

$$\nabla . A = -\mu_o\epsilon_o\frac{\partial V}{\partial t} \tag{31}$$

Now again with this particular gauge choice we can see that equation (26) reduces to:

$$\nabla^2 V - \mu_o\epsilon_o\frac{\partial^2 V}{\partial t^2} = -\frac{\rho}{\epsilon_o} \tag{32}$$

and equation (27) to:

$$(\nabla^2 A - \mu_o\epsilon_o\frac{\partial^2 A}{\partial t^2}) - = -\mu_o J \tag{33}$$

The advantage of Lorenz gauge is that it treats **V** and **A** equally

Gauge transformation in Quantum Mechanics:

Here in quantum Mechanics we will talk about radiation gauge or R-gauge and electric gauge E-gauge through examples which is similar to the method followed in electromagnetic theory.

R-Gauge:

The motion of a free electron as given by Schrödinger equation is:

$$\frac{-\hbar^2}{2m}\nabla^2\psi = i\hbar\frac{\partial \psi}{\partial t} \tag{34}$$

Now an electron of charge e and mass m interacting with an electromagnetic field will have an Hamiltonian of the form:

$$\boldsymbol{H} = \frac{1}{2m}[\mathbf{p} - e\mathbf{A}(r,t)]^2 + e\mathbf{U}(r,t) + \mathbf{V}(r) \tag{35}$$

where **P** is the momentum operator, **A**(r,t) and **U**(r,t) are the vector and scalar potentials respectively and

$\mathbf{V}$(r) is the atomic binding potential. This due to the interaction of the electron with the electromagnetic radiation.
upon further expanding Hamiltonian will be:

$$\frac{1}{2m}[\mathbf{P}^2+e^2\mathbf{A}^2-e(\mathbf{P}.\mathbf{A})-e(\mathbf{A}.\mathbf{P})]-e\mathbf{U}(r,t)+\mathbf{V}(r,t) \tag{36}$$

which can be further simplified as:

$$\frac{\mathbf{P}^2}{2m}+\mathbf{V}+\frac{1}{2m}[e^2\mathbf{A}^2-e(\mathbf{P}.\mathbf{A})-i\hbar\nabla.\mathbf{A}-e(\mathbf{P}.\mathbf{A})]-e\mathbf{U} \tag{37}$$

But here even this is very cumbersome and needs to be further modification and this is where the radian gauge comes into play.

In Radiation Gauge we use:

$$\mathbf{U(r,t)} = 0 \tag{38}$$

and

$$\nabla.\mathbf{A(r,t)} = 0 \tag{39}$$

So in radiation gauge my minimum coupling Hamiltonian will take the form of :

$$\boldsymbol{H} = \mathbf{H}_o + \frac{1}{2m}(-2e\mathbf{A}.\mathbf{P}) \tag{40}$$

or

$$\boldsymbol{H} = \mathbf{H}_o - \frac{e}{m}(\mathbf{A}.\mathbf{P}) \tag{41}$$

where $\mathbf{H}_o$ is the Hamiltonian with out any electric or magnetic field, and the value $e^2.A^2$ is not seen as A^2 is very small so can be ignored

With $\boldsymbol{H}$ being minimum coupling Hamiltonian. One has to remember that $\mathbf{A}$ and $\mathbf{U}$ are vector and scalar potentials and are gauge dependent, where as the gauge independent quantities are $\mathbf{E}$ and $\mathbf{B}$.

Equation (35) originated from gauge dependent quantities, and so it is clear that vector and scalar potentials have much larger significance and are not introduced only for mathematical simplicity as the previous section on electromagnetic theory led us to believe but actually they originate naturally from a gauge invariance argument as we have seen in this section.

Reference:

Introduction to Electrodynamics (Fourth Edition, Prentice Hall, 2013)by David J. Griffiths

Quantum Optics (1st Edition)by Marlan O. Scully, M. Suhail Zubairy

Acknowledgement's:

I thank Dr. R. Arun, Assistant Professor, Department of Physics, CUTN for his suggestions and corrections of this article.

'Perturbations'
Physics Club

This new academic year saw a rejuvenated and better yet chapter for the physics exclusive, science club - "Perturbations". We also saw a great involvement and interest from all the students-who brought in new innovations and more than anything their participation to forward our mission and vision.

At the first meeting, the executive council of students was convened and the road map for the rest of semester was discussed. The other activities included are student seminars, A gaming competition and A special lecture on Learning strategies. We have also initiated ''Daily Answer Writing Challenge'' for CSIR-NET/GATE/JEST exams and the response from the students is highly appreciable.

We would like to thank Prof. H.S.Mani, Chennai Mathematical Institute, Dr. Phandira Narayan Gundu and all other faculty members of physics department, CUTN for their contribution to the department library.

In retrospect, this semester was eventful and we hope for many more activities and much more fun in the upcoming semester. Below are some of the memorable photographs from the past events of this semester.

Dr.K.C.Sekhar
Coordinator Perturbation Physics club
Department of Physics CUTN.

Mr.A.Sulthan Ibrahim
Technical Assistant
Perturbation Physics club
Department of Physics CUTN

HEAD OR TAIL ?

The lecturers were followed by intuitive discussions and question and answer sessions where everyone came together and had fun with science.

Department students, research scholars and faculty members enthusiastically attended the, lectures organized by the physics club.

ALL WORK AND NO PLAY MAKES JACK A DULL BOY

Club organized a LAN gaming competition for students of all the departments, event was attended by many members of the faculty and staff. The club was overwhelmed by the amount of participation.

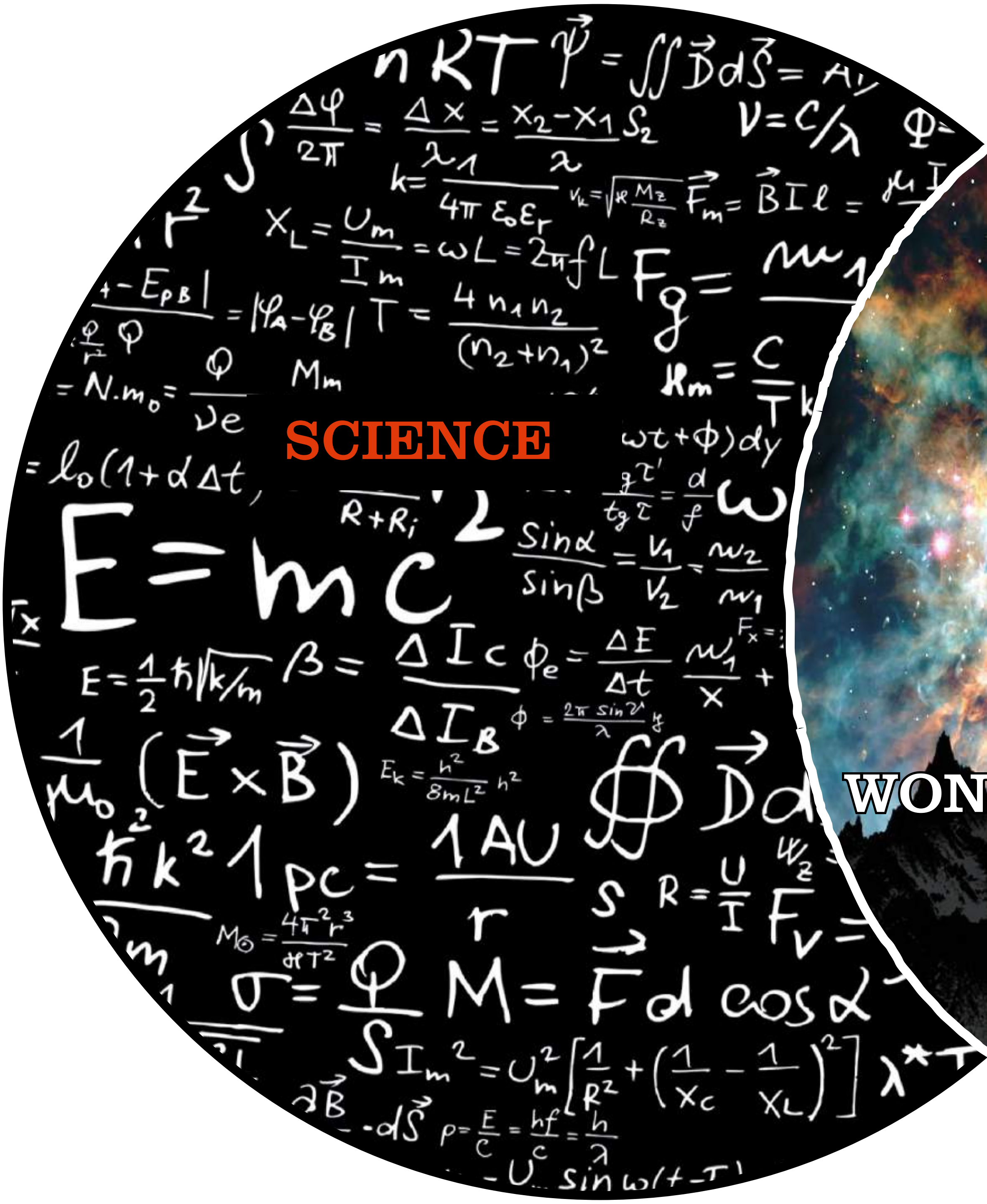
The venue was filled with skyrocketing enthusiasm and fun filled laughs of more than forty participants, at the end of the day jack was indeed not a dull boy anymore.

LEARNING HOW TO LEARN

The seminar had an activity based learning, where different types of learning aid's were demonstrated and if the audience indeed became master learners only time will have to tell.

During a lecture on learning strategies by Dr Biju of Department of Education. This seminar saw a hoard of audience ranging from first year to the senior most of the faculty members, after all education is a life time of learning and we want to be the best

Fifth year iMSc students on their study tour to Kodaikanal


SCIENCE


DER
ART