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insight

Prof. Pradeep Sarin, currently an Assistant Professor in the Department of Physics, IIT Bombay is also an alumnus of the department having graduated from the Engineering Physics B.Tech programme in 1997.

Reebhu Bhattacharya, first year undergraduate, spoke to him about studies, student life, physics and general fundae.

TETE-A-TETE WITH PROF. PRADEEP SARIN

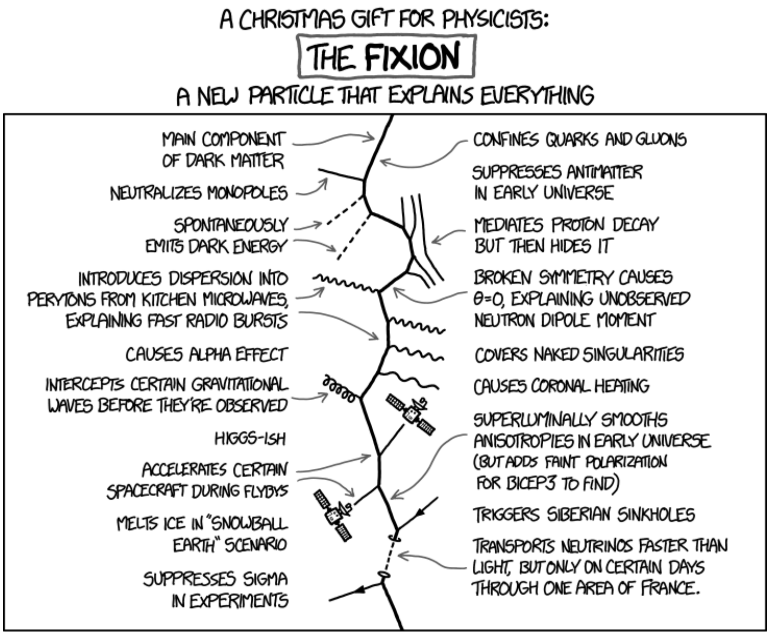
Professor Pradeep Sarin, is an active researcher in the field of experimental particle physics having worked on the CMS experiment at CERN and the LIGO experiment. It is always a delight talking to him as he can engage you at once in a wide array of interesting anecdotes and scientific curiosities. As usual, when I went to interview him for this article at the time we agreed upon, he was busy helping a student with his grad school applications. In the process, I managed to gain a first hand account of things I had not planned on asking him, ranging from his days at MIT to gravity wave detectors. Being an experimentalist at heart, when asked about the so-called distinction between theoretical and experimental physicists, his response is a modified version of a popular theoretical physicist joke, "A theoretical physicist has little importance if he does not know how to change a light bulb." Having heard this statement quite often while working on a summer project with him, maybe I had not contemplated quite so deeply on it, but now I realize the truth in his statement. A theory, after all, must apply to the world we live in and endlessly hypothesizing without any concrete evidence, cannot contribute much. His love for tinkering with things goes back a long way. When at MIT, he had a BMW 6 series car while his flatmate had a BMW 3 series. Together, over weekends, they used to tinker with it, opening up its parts to examine how they work and then reassembling it back by Monday mornings. He also has a passion for tinkering with electronic items, which has been a hobby for him since his MIT days. On being asked about possible research opportunities and whether you need to have adequate knowledge about something before delving into research, he replies that "...that is the whole point of research, you don't study something because you will need it in your research, rather you study it while researching, learning how to tackle new problems". He speaks of how research teams are formed, comprising of members spanning various age-groups and matching personalities. He emphasizes the idea of teamwork telling that it is no use being a 'prima donna' or know-it-all unless you are ready to share your solutions with the team. He further tells that the most important thing in research is to pick the right problems. He tells his own story about an earlier time when he asked his advisor for help regarding choosing a research topic. He was advised to make a list periodically of the most interesting problems in science at the time. Then from the list, select the problem you think you have the best capability to solve and get working on it. Prof. Sarin tells me that one of the problems on his list has been to model thought and consciousness, indicating that the problem need not be restricted to physics and more importantly, they should be important to you and should not be decided by what others perceive as important. He outlines the steps in solving a problem as follows: Select a problem, make some hypotheses to arrive at a solution, check if your hypotheses works and is able to predict new things, ask why the particular solution works/ does not work and now start working on this new problem. This, in short, summarizes the scientific method of tackling a problem, making refined models to explain certain phenomena.

> "A theoretical physicist has little importance if he does not know how to change a light bulb."

> "At any rate, we have not found out everything Nature has to tell us."

He also emphasizes the fact that in order to be awarded a doctoral degree, you need to make some original contribution to the field you are working in. In his words, "Making a small dent, in the boundary of knowledge for that field". When asked about the role of mathematics in physics, his reply is that every physicist needs to know some mathematics, however the important thing is you must be able to see beyond the mathematical equations. He recalls one of his professors at MIT who used to fill up the board with mathematical calculations which however were not all that important compared to the insight he gave into those equations. According to Prof. Sarin, it is this insight that counts a lot, not the mathematical equations which can be reproduced from a book. His views on the expanding horizons of physics is pretty simple, "The different areas of physics are not vastly different, the underlying ideas are pretty much the same." He himself worked both with particle accelerators and gravity wave detectors. He explains that the underlying principle of getting low noise signals is the same in both cases, the strength of the signal is all that differs. He had no problem in shifting from one field to the other, for him it was just a matter of "shifting of office space". On the other hand, he does admit that for interdisciplinary fields like those involving biology, switching over from physics is not so easy unless you have a prior background, which is why he has not tackled the problem of thought and consciousness. When asked about whether the particle physics experiments are reaching some limit beyond which it is simply impossible to make measurements, his reply is that we have not reached the limit yet as imposed by Heisenberg's uncertainty principle. He explains by back of the envelope calculations that theoretically, it should be possible to measure details as small as 10^{-30} of a metre, and that is roughly the reciprocal of the scale by which the universe expanded to its present dimensions. This makes it possible to collide particles such that when the distance between them is of this scale, we observe something similar to a "tiny Big Bang" in the laboratory. And at any rate, we have not found out everything Nature has to tell us. He is quite excited about the search for supersymmetry at the LHC. When asked about physicists he admired, he unusually takes the names of Rainer Weiss and Nergis Mavalvala both of whom are associated with MIT and the LIGO experiment. When asked about the changes from his time as a student and

as a professor now, he tells that initially he found it hard to see the professors who once taught him, as fellow colleagues. He finds that now it has become impossible to teach large classes(the first year students) by classical methods and it is necessary to resort to powerpoint presentations. He also finds that no longer graded problem sets are given every week as used to be the norm in his time, since it has become infeasible to check the large number of papers. Apart from this, he talks of the new option for students to switch over to a Msc program during the B.Tech program not present in his time.



I didn't quite realize how quickly time can pass while talking with him. The realization that I had a class to attend cut short my interview and left me with several unanswered questions. Well, there is always a next time! Meanwhile, I will ponder over the new insights he provided during this short period of time and leave you reflecting over these too.

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HOLOGRAPHY AND ADS/CFT

Holography is the idea that a theory with gravity in a certain number of dimensions is equivalent to a theory without gravity in one dimension less. Why should one expect such a thing to be true? One of the most conspicuous features of Einstein's general relativity is that you can work in any coordinate system you want and still retain the Einstein equations in the same form. This is in stark contrast with say Newtonian mechanics or even special relativity in which the form of dynamical equations are preserved only under very specific kinds of coordinate transformations, namely those involved in going from one inertial reference frame to another. In particular, if you have some rotating frame you will have to put in additional fictitious forces, which compels you to tamper with the form of the dynamical equations. Einstein's gravity is not like that. It doesn't distinguish between choices of coordinate systems, so you know that if you carry out a passive transformation (i.e. a transformation in which the objects of concern are held in place while the coordinate system is moved about), you still have the same equations. However, the distinction between passive transformations and active ones (i.e. transformations in which the coordinate system is held in place while the objects of concern are moved about) is one that exists purely in our minds. The equations themselves don't care how you interpret them. You can do a smooth coordinate transformation that leaves the coordinates and their derivatives on the boundary of some region (and even everywhere outside!) unchanged but transform the coordinates of points within that region. You can interpret this as an active transformation and conclude that if there is a solution to the Einstein equations subject to certain boundary conditions there is a whole infinitude of solutions obtained by carrying out the said active transformations on the solution. This is a problem, since it amounts to saying that there are is an infinitude of solutions to any initial value problem in general relativity!

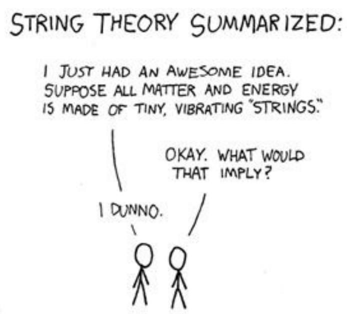
One of the most conspicuous features of Einstein's general relativity is that you can work in any coordinate system you want and still retain the Einstein equations in the same form.

How do we resolve this? We stipulate that to talk of a background spacetime existing a priori is meaningless and that all these solutions related by coordinate transformations are to be regarded as the same physical solution, similar to the way you regard two different solutions to Maxwell's equations for electromagnetism to be physically equivalent if they are related by a "gauge transformation" (these are transformations in which the potential functions associated to electric and magnetic fields are shifted in such a manner that the electric and magnetic fields themselves are unchanged). So, general coordinate transformations are the gauge transformations of gravity. That still doesn't explain why gravity should be different from other gauge theories. Well, the group of gauge transformations in the case of other theories acts on some internal space of phases over each point individually. This is not the case for gravity, where the group of coordinate transformations can send internal spaces at different points into each other, so that it's impossible to define any local gauge invariant quantity that isn't something trivial like a constant function. There's a whole lot more gauge redundancy in gravity than other gauge theories and getting rid of this infinite redundancy amounts to working in one dimension less.

This is in fact consistent with the famous observation made by Stephen Hawking and Jacob Bekenstein in the 1970s that the entropy of a black hole is given by the area of its event horizon. This means that the maximum amount of information (which is just another word for entropy) you can cram into a sphere is bounded above not by something proportional to the volume of the sphere but by the surface area. This strongly suggests that if you have a theory of gravity, the physical degrees of freedom live in one dimension less.v The AdS/CFT correspondence, discovered in 1998 by Juan Maldacena, is a spectacular realisation of this that basically turns the above idea on its head. Namely, it says that if you have a theory symmetric under angle-preserving transformations (referred to in jargon as a conformal field theory, abbreviated to CFT), you can pretend it lives on the boundary of a higher dimensional anti de Sitter spacetime, which is abbreviated to AdS. This is like a high dimensional version of a Pringles crisp, and the reason we need it is that unlike ordinary space, in which surface area scales as the square of length while volume scales as the cube of length, the surface area and volume of a sufficiently large region in AdS spacetime scales the same way. In particular, this means that the time taken by a light signal to travel from one point on the boundary to another through the interior and along the boundary are the same. This is crucial in order to ensure that you don't have nonlocal interactions on the boundary theory as a result of effects in the interior. The need for a CFT follows from the fact that the group of symmetries of AdS is essentially the same as the group of angle-preserving transformations at the boundary. The statement of AdS/CFT is the following. Say you have some theory on the boundary and you write down a sum-over-configurations for all the fields in the boundary theory in presence of a source that, as Richard Feynman had shown in the 1940s, describes how those fields propagate in a quantum theory. Since you sum over all the dynamical fields on the boundary, what you are left with is a function of the source. If you are familiar with statistics, you may think of this as a moment generating function, from which you get the moments by taking derivatives with respect to the source variable. And save for certain caveats, you know a theory once you know all the moments (also called correlation functions). So, this sum-over-configurations carries with it the blueprint for the entire field theory on the boundary. AdS/CFT gives you a another way for obtaining this sum-over-configurations. You begin by pretending that the source in the boundary theory is the boundary value fo of a dynamical field f in the interior. Now, you compute the sum-over-configurations for the gravity theory in the interior of the AdS space by only summing over field configurations that take the required value at the boundary (namely f_0). The resulting sum-over-configurations for the interior theory can therefore be written as a function of f_0. Now the two sums-over-configurations corresponding to the theory on the boundary and the theory in the interior are different beasts since the dynamical fields whose propagation they describe are different. Yet both of them are functions of f_0. The AdS/CFT prescription is that these two sums-over-configurations, although different in terms of interpretation, are formally identical.

So, general coordinate transformations are the gauge transformations of gravity.

This doesn't seem to be helping much. All we seem to have done is replace computation of one sum-over-configurations by another. But the real power lies in the fact that when the boundary theory is in a regime in which traditional ways of computing correlation functions by perturbing around some known solution break down owing to the perturbation parameter becoming



too large, the interior theory is in a regime in which the quantum corrections become negligible. So you can approximate the interior sum-over-configurations by taking just the contribution from the classical solution satisfying the classical equations of motions for f subject to the boundary condition imposed by f_0. In effect, you have thus reduced a calculation you couldn't have done by perturbation theory to one that simply requires you to solve some classical equations of motion.

But that is not all. There is a pretty nice way to interpret the new direction that going to a higher dimension introduces. It corresponds to "zooming out" in the boundary field theory. That different ways of "zooming out" become different ways of slicing the interior theory is what essentially makes the AdS/CFT correspondence so powerful.

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GRAD STUDIES 101

INTRODUCTION

Whenever I am asked what is the difference between Physics students and others, the answer which jumps straight to my mind is "Magic" !

I am speaking with enough hindsight that this passion can be maintained beyond your first year! And many with vastly more experience than me will agree. When you know a lot more about how the universe works: how stars are born, why the light from a laser does not spread like light from a torch, how computing and memory devices work, what magic quantum computers can enable, how we can 'charm' electrons, photons, atoms to behave according to our will; you do feel rather special. It is essential to have a deep passion in the subject before you consider research as a career in that field. In this article I will try to address questions which I received over the years as a mentor and friend from many students. But I strongly encourage readers to contact relevant people in their field. Most EP students have been traditionally very helpful and most professors will be happy to provide guidance on a diverse range of issues concerning students. There is a great synergy in the department which has benefitted everyone and I hope you make sure to use it to your advantage. This article will contain my take on issues which may differ from your view and my view can simply be outdated, wrong, misinformed. I have endeavored to write this because different views will help form a better view in the end.

BACKGROUND

The first question many of us encounter is: "Am I suited to research? Is this what I really want to do?" Needless to say that strong passion is a must. The best way to know this is to do research oriented projects in your institute and other places, if possible. Physics department at IIT-B is one of the very best in India and is excellent to give you enough exposure. A common misconception I can spell out, is that not every good wizard is Hermione! Sheer brainpower matters, but is not the only crucial things which go into making of a great researcher. Everyone has their own methods of working things out. It is not like coursework, where you have an established curriculum, fixed learning goals, existing methods of working things out. It is an 'experience' and best way to figure this out is to 'experience' it in projects and see if you'd like to do more rigorous and intense version or not !

> "A very common misconception I can spell out, is that not every good wizard is Hermione!"

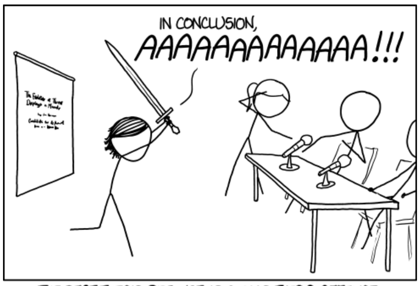
PREPARATION

Throughout my years at IIT-B I have been fortunate enough to meet many students very excited about research. Though it is great to have that zeal, I think enjoying your stay at IIT-B and doing things which you like viz. doing relevant courses and projects, naturally prepares you for a good PhD. Motivation is good, but sometimes there is too much obsession among students which I think should be checked. "Karmanye Vaadhikaraste" is the way to go in this case. Like a course or a project? Do it, without losing sleep over whether it is going to matter in your grad school applications.

There have been many debates over depth (a lot of experience in one field) vs. breadth (some experience in many fields). What I feel is that as long as you do what your scientific temper tells you and you justify it in your statement of purpose, which every university will ask for during admission, you are fine. Since the challenges faced and skills needed for a PhD will be at a different scale, it is not very likely that the undergraduate experience will sway the admission decision very much. Putting it simply, people are likely to look for raw talent, not specifics. (At least this is what I experienced at Cornell or to push it, in US system of graduate admissions) There is also a lot of debate on importance of CPI, so called 'foreign interns' etc. Scores matter, so don't be too lazy about them. So does everything else (projects, scores, advanced courses, basically general experience/ interest in scientific research shown by whatever parameters you can present) But none of the parameters are weighted in such a skewed manner that not having one of them shining is devastating for your prospects. It is essential to be optimistic and aim high.

ADMISSION PROCESS

While I am at it, I think I should also document this though keeping in line with previous section, I think people should not worry about this until their last year. I had applied in US universities so I can only outline a rough sketch of US system. You need to take the GRE (Graduate Record Exam). This exam tests your vocabulary, analytical skills and quantitative skills. Then a GRE Physics is required for students who want to continue their research in Physics. But it must be said again that one should not be too lazy (or on the other hand too nervous) about them. For spoken English either TOEFL or IELTS is required. All exams are reasonable and with enough



THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.

preparations, everyone can do well.

RESULTS & DISCUSSION

In this section, I would like to share my experiences in my PhD program in hope that it will help you make an informed decision. What I feel is that if you enjoyed student life: the freedom of thought, the exhilaration of figuring things out, the campus life, great company of like minded peers, you will love to be in grad school. The problems you work on a PhD are completely open ended and in most cases, an unsolved

> Putting it simply, people are likely to look for raw talent, not specifics

mystery! There is certain thrill you experience as you discover things for your own. And of course there are chills accompanying the thrills as things don't turn out as you expected them to be. There are lots of highs and lows. This is where I think the passion which I keep repeating comes into picture. This magnifies each high to give you a sense of bliss and changes your perspective towards lows so that you can take them to be an important source of learning and continue undeterred in your search with same zeal. I would like to suggest here that this is very different from the coursework we do. We may find the Physics very interesting as we learn fascinating things from our professors about Nature. A research career is actually putting ourselves into action to find things out. It is important to know the distinction, hence the point I made earlier about getting as much research exposure as possible. Many of the questions are directed towards funding and economical aspects of a research career. As far a PhD is concerned, speaking from a US system and from experience of my peers and seniors, a very decent stipend makes sure that your lifestyle is very good. In short, generally the amount suffices for most of the needs. A decent saving is also very common. Considering the fact that the tuition fee is waived off and you get world-class facilities (libraries, computational facilities, experimental equipment etc.) to do what you love, I think it is very fair in the outcomes.

CONCLUSION

We all love Physics, but to choose research as a career, there are some additional considerations which were discussed in the article. I tried to address some common concerns. EP has been historically a great powerhouse of world class researchers. I hope this article contributes to the information pool for making an informed decision.

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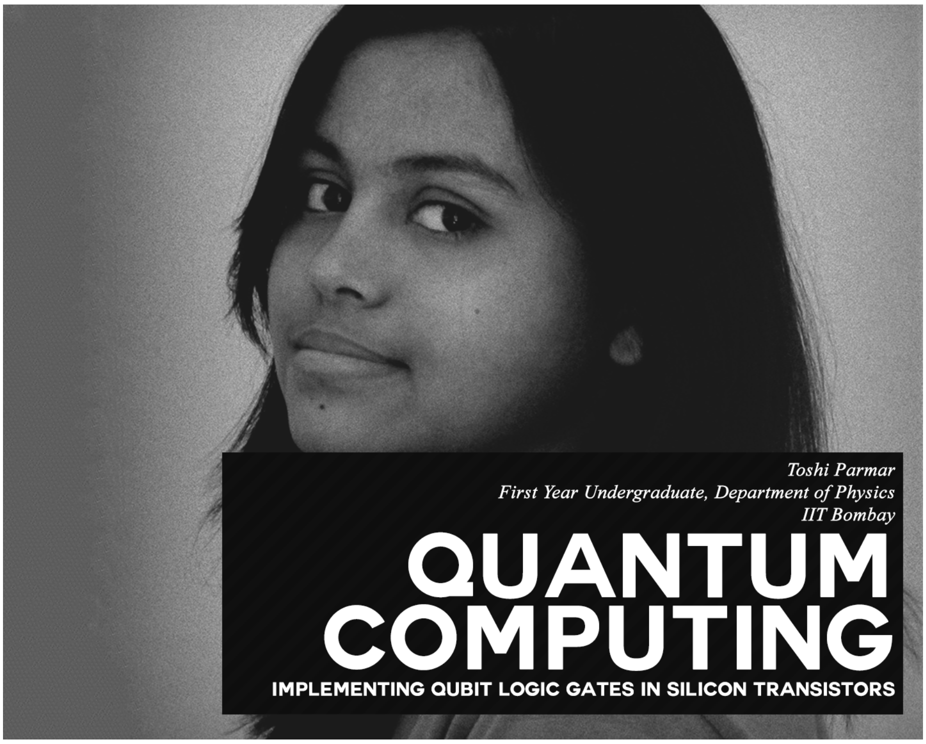

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QUANTUM COMPUTING

IMPLEMENTING QUBIT LOGIC GATES IN SILICON TRANSISTORS

A team of researchers at The University of New South Wales(UNSW), Australia, led by Andrew Dzurak have successfully accomplished the making of a two qubit logic gate in silicon, which is a crucial hurdle overcome in making quantum computers a reality.

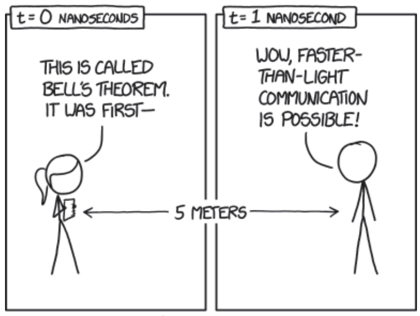
> "We've demonstrated a two-qubit logic gate - the central building block of a quantum computer - and, significantly, done it in silicon. Because we use essentially the same device technology as existing computer chips, we believe it will be much easier to manufacture a full-scale processor chip than for any of the leading designs, which rely on more exotic technologies."
> "This makes the building of a quantum computer much more feasible, since it is based on the same manufacturing technology as today's computer industry," team leader Andrew Dzurak, Director of the Australian National Fabrication Facility at UNSW

newsroom.unsw.edu.au/news/science-tech/crucial-hurdle-overcome-quantum-computing

The key idea behind the working of the UNSW team has been the morphing of normal transistors, used to define bits in silicon chips today, into defining quantum bits or 'qubits', by ensuring that each transistor has a single electron associated with it, and representing the binary equivalent of numbers 0 and 1 by spin of the electron.

INTRODUCTION

The ideation for representing qubits as the spin of an electron was primarily proposed in 1968, and sparked up with eminent physicist Richard Feynman proposing the possibility of a quantum computer in 1982. Essentially the concept involves use of quantum bits or 'qubits' instead of conventional bits, that can be coupled in a scalable manner to make up one and two qubit logic gates. The numerous physical realisations of qubits- single photons, silicon and semiconductor quantum dots etc. have to be sufficiently fault tolerant and conserved under time evolution, with discrete and spaced eigenvalues that can be mapped onto an effective spin-1/2 system.



BELL'S SECOND THEOREM: MISUNDERSTANDINGS OF BELL'S THEOREM HAPPEN SO FAST THAT THEY VIOLATE LOCALITY.

WHY QUANTUM COMPUTING

The edge that a quantum system has over the conventional is the property of entanglement and superposition of states, i.e. a qubit's existence is governed by superposition of the two basis states that denote conventional bits 0 and 1, mathematically, a linear combination. Thus considering two interacting qubits, four possible combinations yield, each weighed by a coefficient that denotes the probability of existence of the system in that state. $(a|00\rangle + b|01\rangle + c|10\rangle + d|11\rangle)$ To specify a combination of two conventional bits, two numbers are needed ie. the value of both the bits, while for the quantum system the four coefficients. Thus the information represented by an 'N' qubit system is exponentially large in comparison with its classical counterpart (N bits), the former is essentially 2^N.

QUANTUM ALGORITHMS

Since the state of superposition cascades down to one of its basis states on observation, termed as the collapse of the governing Schrodinger wave function, specific algorithms have to be applied to extract information out of a quantum system. Many brilliant minds have risen to the occasion, among them, notably and famed are Peter Shor (Shor's Algorithm, 1994), Daniel Simon (Simon's Algorithm, 1994) & Lov K. Grover(Grover's Algorithm,1996).

Many of the quantum algorithms give probabilistic solutions, solutions with probability very close to one, & which can be improved upon by repeated iterations but nevertheless its probabilistic. Many others however, are fully deterministic

and hence efficacious.
The quantum computers can only respond to specific algorithms and tasks exponentially efficiently than classical, thus, they are not the substitute for them, but an aid, for more technological and advanced sectors. Not every task that a normal personal computer does can be effectively performed with them. Nevertheless, new possibilities in quantum simulation and computing sciences have dawned just because of them.

HURDLES ON THE ROAD

Interaction of the qubit(s) with the environment leads to decoherence which is irreversible and non-unitary and thus must be controlled if not eradicated. A big hurdle now is to remove the decoherence from the system, isolating the system from the surroundings, cutting down its interactions that make the system decohere, and to do so economically and feasibly.

Another problem that is now faced is to scale this system up to vast numbers of stable qubit registers or "q-registers", quantum mechanical analogues of classical processor registers. In this direction, Dzurak notes that the team has "recently patented a design for full scale quantum computer chip that would allow for millions of our qubits, all doing the same kind of calculations we've just experimentally demonstrated."

THE WAY FORWARD

The UNSW team's research breakthrough has attacked three of the major requirements - qubits that can be initialised to arbitrary values, qubits with successful readout fidelities and an universal CNOT quantum gate faster than the decoherence time of the system. Improvement by lowering the sensitivity to electrical noise is targeted next. Though the two qubit system represents the smallest scalable system so far, it is consistent with current transistor sizes, offering the prospect of realizing a large-scale quantum processor using the same silicon manufacturing technologies that have enabled the current information age.

And lastly, on a more tender note, "Computers are physical objects, and computations are physical processes. What computers can or cannot compute is determined by the laws of physics alone."
- David Deutsch

EXPLORING SHOR'S ALGORITHM

Shor's Algorithm is an algorithm designed to be run on a quantum computer which takes a number N and outputs its factors. The best known algorithm for factoring prime numbers on a classical computer requires an amount of time that is basically exponential with the size of N. This is why Shor's Algorithm is considered important--a quantum computer running it would only require polynomial time. Since the security of the popular RSA cryptosystem is based on the difficulty of prime factorization, Shor's Algorithm has attracted a lot of interest from the privacy and data security communities.

The basic gist of Shor's algorithm is the process of period-finding which is done by the Quantum Fourier Transform (QFT). The QFT takes some function f(x) and figures out the period of the function.
So how does the QFT actually work? Consider an experiment where people are locked for weeks in a sealed room without clocks or sunlight, and the people gradually shift from a 24-hour day to a 25- or 26- or 28-hour day. One day they'll wake up at 9am, the next day at 11am, the day after that at 1pm, etc. Now, here's the question: let's say that they woke up at 5pm this afternoon. From that fact alone, what can you conclude about how long their "day" is? The answer, of course, is not much!
Now imagine that their bedroom wall is covered with analog clocks. Very strange clocks: one of them makes a full revolution every 17 hours, one of them every 24.7 hours, and so on for every number of hours you can imagine. Beneath each clock is a posterboard with a thumbtack in it. Initially, each thumbtack was in the middle of its respective board. But now, whenever they wake up in the "morning," the first thing they do move each thumbtack exactly one inch in the direction that the clock hand above it is pointing.
It follows, then, that just by seeing which thumbtack travelled the farthest from its starting point, you could figure out what sort of schedule they are on. In other words, you could infer the "period" of the periodic sequence that is their life.

The QFT can be done efficiently on a quantum computer, because it can have all of the "clock experiments" running at once in superposition, with the bad experiments deteriorating from destructive interference effects and the good experiments dominating from constructive interference effects. The rest of Shor's algorithm is entirely a classical algorithm. Once we have the period-finding mechanism of the QFT, we can exploit it to find patterns in the mathematical structure of the number we're trying to factor, N. In particular, we find the period of a^x mod N, where a<N. If N=77, a=22, then the QFT will tell us how long we have to continue in the sequence of 22^1, 22^2, 22^3 mod 77 and so forth until we reach 22 again.

From there, we just borrow a result from number theory that usually yields a factor of N. The result is that the greatest common denominator of N and $a^{(period/2)}$ is a factor of N.

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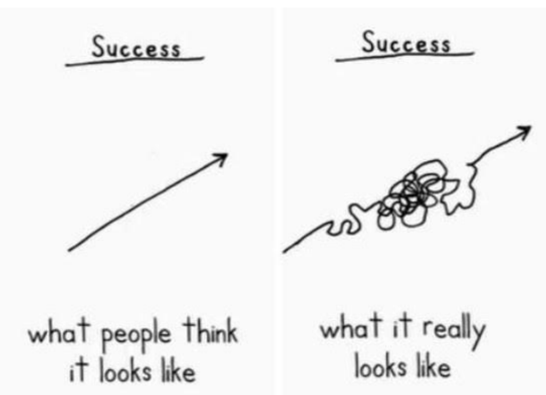
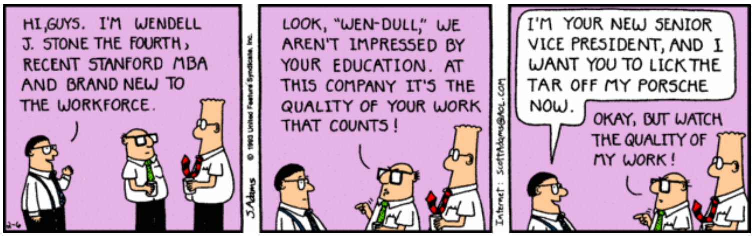
THE PATH LESS TAKEN

Very few of us join a branch for the branch. Heck, we don't even bother to go through the curriculum. We join IIT Bombay and what appears to be the best branch our ranks would fetch us. And that is perfectly alright – you are barely an adult and in any case, to be honest, no one prepares us for making this choice. Then over time a few of us develop a liking for the course, a few of us become indifferent and the remaining manage to learn what's being taught but are not really going to pursue physics. By your second or third year you are pretty much either completely lost or in it. I am not talking to the ones in it – good luck to you people and you can avoid reading further. I am not the best candidate to advice the ones who truly want to pursue physics or any other engineering for that matter. For the rest, who understand that they have left the opportunity to understand and apply their engineering curriculum far behind in some forlorn corner of their previous semesters, there is another great opportunity to regain the academic momentum that gave you the respect and recognition of your coaching class days. And more than that, you must understand that this is the age where you would want to invest in yourself, learn and pick up skills that allow you to be a valuable person and this also is the age where you have the freedom to be a student once again. Plus in today's world, you can rarely succeed with technical skillset – you will have to be a master at your art and if you are not, you might remain a glorified analyst or engineer at some giant multinational. With this in mind, I would like to propose a road less taken, particularly by the students of our department - a postgraduate program in management.

> "The core skill of every IITian – the ability to learn and adapt and apply faster and better than the rest."



I was a 6 pointer in my 4 years, and then I worked with Housing.com for about 10 months. I gave the CAT, secured a 100%ile and am currently institute rank 12 out of 450+ at IIM Calcutta. I have an internship with Bain and Company as an associate consultant and will mostly be going on a semester exchange to a top business college in Europe to get a second degree, the Masters in International Management, ranked 5th in the world by the Economic Times. All these I hope you would agree are reasonably decent achievements for a 6 pointer. But my biggest achievement is that I have regained a faith in myself and my abilities that only excelling at learning could provide. I decided to give myself another shot at studies, to attend classes, to gain back the spark of inquisitiveness and leaning and the desire to excel in competition. Choosing to do a PGDM (since IIM degrees are not really an MBA in technicality) was a decision not taken for a good job or higher salary (although they are quite pleasant side effects). Choosing to study further was to give myself another shot at reigniting the core skill of every IITian – the ability to learn and adapt and apply faster and better than the rest. Also, this path opens up a broader world – a world of business and industry that engineering is not created to open up. You develop skills that are valuable throughout industry, in all sorts of companies and more importantly, are applicable in daily life. Starting from abstraction like time management, team work and forced night outs, you get to pick up more objective nuances of finance, strategy, operations, marketing and much more. Moreover, you can reinvent yourself and get out of the vicious cycle of lack of interest – low grades – further drop in interest – lower grades and so on.



So I would request some of you to give an MBA a good thought – work for a year or two, get in that competitive exam mode all IITians are good at, crack the CAT/ GMAT, join a good management institute, work hard, learn, attend classes, make friends with professors, secure a good intern and subsequent job, or figure out a way to open up your own firm, and come out as an individual keener and sharper than you are right now. Don't get stuck in the rut of corporate slavery where the only reason you were hired was because you cleared some exam 4 years ago and all you do is maths and coding. Give education another shot and you can leapfrog to a much better stage in career and life. This is like those green pipes at the end of level two in Mario Brothers. It's an investment of time and money at the end of which you will have good returns. Think over it, and if you need help, you can always connect with me or any other senior you are comfortable with. I have observed that IIT alumni love to help our juniors.

Machao ! :D ■■■

LIGO EXPERIMENT EXPLAINED

-by Umang Mehta

In light of the recent announcement from LIGO we talked to Prof. Sarin regarding the verification of gravitational waves and its implications.

ABOUT THE ANNOUNCEMENT

LIGO has confirmed the existence of both gravitational waves and black holes. While we had indirect evidence of black holes, any uncertainty is now cleared as the signal detected matches precisely with the signal expected for a binary black hole system.

ABOUT LIGO

The LIGO experiment is headed by Prof. Rainer Weiss who proposed it in 1973. Prof. Sarin talks about his enthusiasm noting how Dr Weiss would stay back much later than others working on something or tinkering about in the lab.
For the experiment 14,000 feedback loops which emphasises the scale of fine tuning required.
Noise isolation is also of paramount importance. Prof. Sarin recounts an anecdote of a grad student who researched a signal obtained from LIGO for two years. However this turned to be a false alarm as the signal was concluded to be due to disturbances from two airplanes flying over both the observatories.

IMPLICATIONS

The announcement paves the way for the advent of gravitational wave astronomy. As was announced in the press conference we find ourselves in the same situation as Galileo when he pointed his telescope towards the sky. The ability to detect gravitational wave signatures from astronomical and cosmological sources will refine our understanding of the universe to a much greater degree than achieved by electromagnetic wave astronomy.
Gravitational waves couple weakly with matter giving us a much more direct picture of the sources as opposed to electromagnetic waves which would be affected by obstructions in their path. This might even help to understand the early origins of the universe with an accuracy not possible by the resolving ability of electromagnetic waves.
We now also have constraints on the mass of a graviton. Similar experimental data from gravitational wave astronomy would give impetus to the development of a consistent renormalisable* theory of quantum gravity.

*Current theories blow up in the high momentum limit

LAB IN FOCUS

THE PHOTONICS AND ULTRAFAST OPTICS LABS

The focus of the Photonics and Ultrafast optics labs is to explore light-matter interactions in various types of physical systems at different length & timescales to get understanding of essential fundamental mechanisms. A wide variety of elementary physical processes occur on ultrafast femtosecond timescale. A well known examples are the motion of electronic wavepackets in atoms and molecules and the somewhat slower dynamics of vibrational wavepackets in molecules, typically occurring on 1-100 fs time scales. Other relevant processes include energy transfer processes in semiconductors, biomolecules and natural as well as artificial light harvesting complexes. So far, ultrafast optical spectroscopy is the only technique that can give real-time information about these processes. During the last two decades, it has rapidly advanced providing time-resolution down to the fs range and even below. Recent examples of its ever expanding application domain include the investigation of surface plasmon polariton dynamics in metallic nanostructures occurring also on time scales of 1-100 fs. In our labs, we use ultrafast spectrosocpy and photonics techniques to study some of the cutting-edge research areas like nonlinear optics, ultrafast phenomena, molecular spectroscopy, nano-optics and plasmonics.