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The Academy of Physics Teachers, Kerala

Contents

Editorial

Academy of Physics Teachers, Kerala is a professional organisation of Physics teachers in colleges and universities in Kerala. Launched in 1999, it has been organising a series of programmes such as curriculum workshops, short refresher courses, invited talks by eminent persons and talent search examinations. One of the notable achievements is the continued publication of the bulletin ‘APTunes’. Launched in 2000, this is into the fourteenth year of publication.

In the last few months we have seen important breakthroughs in the field of Physics. It was on July 4th 2012 that an international team of scientists working at the Large Hadron Collider at CERN announced the discovery of a new particle that is thought to be the long sought after Higgs boson. What is confirmed is that we have seen a new particle of mass around 123 GeV/c^2 and that it is a boson. We have not yet verified whether it is the spin-0 fundamental particle named after Peter Higgs - the only missing piece in the successful standard model of particle physics. This achievement was only possible through the concerted effort of a few thousand activities from a large number of countries including India. Our institutions involved in this include the Bhabha Atomic Research Centre (BARC), Mumbai; Tata Institute of Fundamental Research, Mumbai; Raja Ramanna Centre for Advanced Technology (RRCAT), Indore; Variable Energy Cyclotron Centre (VECC), Calcutta; Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam and several universities.

Another area of research and explorations in which exciting developments are taking place is astronomy in which ever bigger telescopes are being built and new solar like planetary systems are being discovered. India also is playing a significant role being part of the international group in the process of establishing a 30 metre telescope on Mauna Kea in Hawaii.

One of the notable megaprojects of international standard that is being implemented in India is the India-based Neutrino Observatory that uses 5,000,000 kg magnetised iron as the medium to detect atmospheric neutrinos. This is an indigenous project that builds on Indian expertise in the field. This is being set up in the West Body Hills in the Theni district of Tamil Nadu, quite close to the Kerala border.

In Kerala too Physics research is undergoing a silent revolution through the establishment of a large number of research centres based in the Post Graduate Departments of various affiliated colleges by availing opportunities and funds offered by national institutions such as the University Grants commission, Department of Science and Technology, Council of Scientific and Industrial Research etc. A list of such research centres is being published in this issue of APtunes.

Looking forward to more exciting news and events.

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2013 - Centenary of Bohr Atom Model

Physics Nobel Prize 2012
Trapping Ions, Photons, and the Schrödinger Cat

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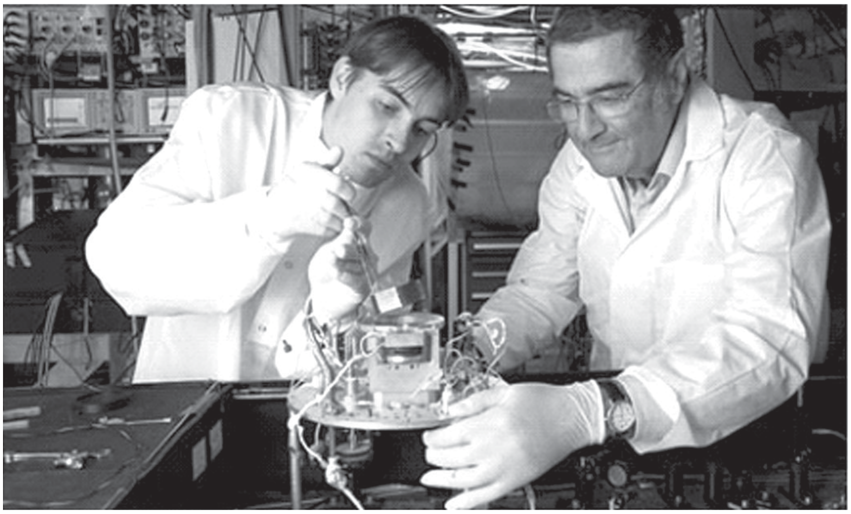
Imagine that we are watching the live coverage of the world cup cricket on TV. An aerial view of the stadium is similar to our perception of a macroscopic object in physics. A macroscopic object is like a packed crowd at the stadium waiting for the big game to start. There is constant movement, a buzz of excitement, anticipation and perhaps isolated activity as someone here or there makes a joke for the people around to share. The crowd of atoms, like the spectators, generates a lot of incoherent noise in random directions and starting at random times. Their activity cannot be detected and measured unless the atoms are isolated in a cold, dark vacuum and studied one by one. We can only detect collective excitations in a crowd such as a Mexican wave if we are looking from far. Such excitations can be termed as coherent, detectable and measurable. But the question is how and how long can we observe such phenomena when we move away from the small to the daily world around us?



Serge Haroche, winner of 2012 Nobel prize in physics, with Igor Dotsenko working on his optical trap.

Classical physics presents us a less confusing picture of the physical world around us. The world behaves in a familiar and predictable manner when we observe day to day events and earthly or heavenly objects visible to ordinary folks. We don't observe a person being present simultaneously at two places, even though many works of fiction would fancy such possibilities. We also cannot feel any errors of measurement due to the uncertainty principle as hypothesized by Heisenberg. However, we all know that modern physics presents us the picture of a world underpinning the observable world. This world runs on ideas counterintuitive to our feel of the classical world. This quantum world presents us weird picture of a microscopic world in which particles can exist at two places simultaneously and very close to one another than anything we can imagine.

The state of being at two different places simultaneously is called *coherence* and the strong correlation between particles states is called entanglement. Once we enter the classical world (i.e. the one we experience every day with our senses) phenomena such as coherence and entanglement cease to stimulate our senses. Scientists have long been working hard to explain this quantum-classical disparity and they were quite successful in stretching the limits of quantum-classical boundary to easily observable world. The beginning of such studies could be traced back to the famous *Schrödinger cat* experiment which was presented by Erwin Schrödinger in the form of a paradox. According to this famous thought experiment quantum mechanics would allow a cat kept in a chamber along with a random source of poison to be both dead and alive at any instant. But we don't see any such events in real life and poses us with dilemma about quantum-classical realities. The Nobel Prize in Physics for the year 2012 has been awarded to two leading researchers, *Serge Haroche* and *David J. Wineland,* who strived hard to isolate individual particles of matter and light that interact strongly with their environment. Their work, spanning over a few decades, gives us a better idea about how quantum particles lose their identity when they form ensembles of matter through collective interactions.

Trapping Ions, Atoms and Photons

By the end of twentieth century, a technique called *laser cooling* has been developed to perfection by scientists to capture and control individual ions and atoms with the help of intense laser pulses under very low temperature conditions and ultrahigh vacuum. Professor David J. Wineland and his team worked mainly in this area over decades and they mainly used a trap called Paul trap. In this mechanism, ions and atoms are held under a strong laser field with the help of oscillating electric field. They perfected the art of manipulation and detection of individual ions with the help of laser photons. This paved the way to highly precise atomic clocks for time measurement and to the development of quantum computing with trapped ions which is a hot area of research and development today.

Physics Professor David Wineland in his lab at the National Institute of Standards and Technology (NIST) in Boulder, Colorado

Advancement in the field of Cavity Quantum Electro Dynamics (CQED) since the 1980s led to the development of optical trapping and control. Several groups working in this area have shown interesting phenomena such as one-atom maser, two-photon micro-maser, and several applications in quantum optics and quantum information theory. Haroche and his group pioneered the art of trapping photons in microwave cavity with the help of superconducting *Nb* mirrors acting as a perfect resonating cavity. The optical field in the high quality cavity is then probed by *Rb* atoms prepared in a circular Rydberg state (e.g. $n = 50, l = |m| = 49$). These atoms do not absorb the photons but their energy levels get Stark shifted inducing a phase shift in the optical field. This phase shift is of the opposite sign, depending on whether the atom is in the $|\uparrow\rangle$ or $|\downarrow\rangle$ state, leading to an entanglement of the atomic and field states. The number of photons in the cavity could be measured by a technique called the quantum non-demolition measurement. This has led to experiments where the *progressive collapse* of a wave function has been observed by means of non-destructive quantum measurements in a quantum analogue of the Zeno's paradox. The usual methods of measuring photons destroy them, so they can be measured only once. The Haroche group at *l'Ecole Normale Supérieure* in Paris has advanced this nondestructive measurement technique so that it can be repeated hundreds of times to record the entire history of a single photon.

Study of Schrödinger's cat paradox

The paradox seeks an answer to the question "does a quantum system cease to exist as a superposition of states (*coherent states*) and become one or the other?" The loss of this superposition to a statistical mixture of states is called *decoherence*. Studies led by Haroche and Wineland addressed this problem with the help of trapped photons and ions. It is well known that measurements carried out on a coherent mixture would lead to decoherence as well as interaction of the system with the external world. Haroche's group prepared a superposition of cat-like microwave field states was created by entangling a Rydberg atom with the cavity field. The decoherence of this superposition, i.e. its evolution towards a statistical mixture, could be measured as a function of time and the properties of the superposition of states.

Wineland and coworkers performed similar experiments using ion trap technology. They created *cat states*consisting of single trapped ions entangled with coherent states of motion and observed their decoherence. Recently, Haroche and coworkers created cat states, measured them and made a movie of how they evolve from a superposition of states to a classical mixture. This extraordinary control has also led them to implement quantum feedback schemes in which the effects of decoherence are measured and corrected for, thus *stabilizing* a quantum state.

Applications

Preparation of entangled states with a larger number of particles is a prerequisite for the development of quantum computers. Quantum computers perform computation using quantum bits or simply *qubits*. The Nobel laureates of 2012 helped to prepare qubits into hyperfine levels of trapped ions, which interact very weakly with the environment and therefore have long lifetimes. Wineland and his group were the first to carry out experimentally a two-qubit operation (the Controlled NOT gate, CNOT) between motion and spin for Be^+ ions. Today, the most advanced quantum computer technology is based on trapped ions, and has been demonstrated with up to 14 qubits and a series of gates and protocols.

An important application of Wineland's research with trapped ions is optical clocks. Clocks based on a transition in the optical domain are interesting because the frequency of the transition, which is in the visible or ultraviolet range, is several orders of magnitude higher than that of the Cs clocks operating in the microwave range. Optical clocks developed by Wineland and coworkers currently reach a precision just below 10^{-17}, two orders of magnitude more accurate than the present frequency standard based on Cs clocks. The accuracy recently achieved by the optical clocks has allowed Wineland and coworkers to measure relativistic effects, such as time dilation at speeds of a few kilometers per hour or the difference in gravitational potential between two points with a height difference of only about 30 cm.

In summary, David Wineland and Serge Haroche have been rewarded for their invention and implementation of new technologies and methods allowing the measurement and control of individual quantum systems with high accuracy. Their work has enabled the investigation of decoherence through measurements of the evolution of Schrödinger's cat-like states, the first steps towards the quantum computer, and the development of extremely accurate optical clocks. ■

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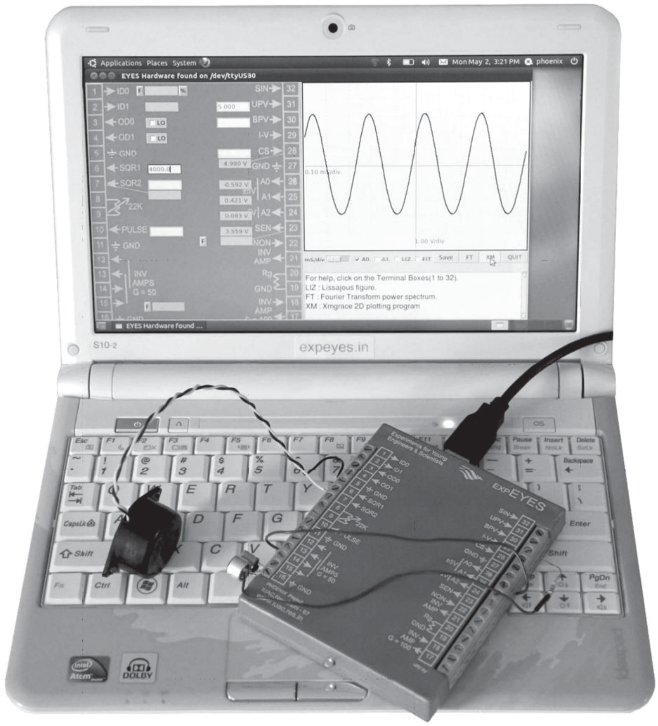

ExpEYES (Experiments for Young Scientists)

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ExpEYES is from the PHOENIX (Physics through HOme made Equipments and iNnovatIve eXperiments) project of the Inter-University Accelerator Centre, New Delhi. It is a hardware & software framework for developing science experiments, demonstrations and projects and learn science and engineering by exploration, capable of doing real time measurements and analysing the data in different ways. It is a miniature form of the high end physics experiments, like LHC, where the actual collision happens only for fraction of a second. Then using sensors kept around the experimental setup, the data is collected and later analysed. If you want to teach the students, such modern method and to do the conventional experiments using the power of computers, here is an equipment for you.

The expEYES hardware is interfaced and powered by USB, having a size of 11 x 9 x 1.5 cm and weighs 150 gm. There are 32 terminals arranged in two rows where you can connect external signals, within +/-5 volts range, for control and measurement. It can function as a signal generator, frequency counter and low frequency oscilloscope . The user manual documents about 50 experiments, that can be done using expEYES and the Standard Accessory set. Analog voltages, in +/- 5 volts range, are measured with 12 bit resolution (around 1.25 millivolts) and time intervals with one microsecond.

ExpEYES hardware consists of an ATmega32 micro-controller, 12 bit ADCs and DACs, several Oscillators and Amplifiers. The micro-controller manages all the hardware resources as per the instructions from a PC. The software running on the PC side is written in Python programming language. It can run on any system having a Python Interpreter and a Python library for communicating to the Serial/ USB ports.

This project is based on Free and Open Source software, mostly written in Python programming language. The hardware design is also open. A science laboratory at home becomes an affordable idea, with expEYES, costing around Rs.3000/- and the structured design supports adding more experiments without much effort. The standard accessory kit cost comes around Rs.1200/- which include the CD and User manual. If you have a laptop or PC, you can easily install the software and do the experiments. ■

Kindly visit : www.expeyes.in

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OLED Displays : Coming of Age

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Introduction

Though organic electroluminescence has been known since 1953 after the experiments of Bernanose and co-workers [1], it was only in 1987 a practical device was demonstrated using the principle. C W Tang and Vanslyke, two Eastman Kodak scientists, reported the first organic light emitting diode (OLED)[2]. Since then, OLEDs have been a hot topic for research both in industry and academia and today they are poised to replace the other display technologies like LCD, PDP and CRT.

What is an organic semiconductor?

These are carbon rich compounds where the material properties are governed by molecular properties. The molecules are held together by van der Waal's forces and the electrical conduction happens by hopping. The highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) are analogous to valance band and conduction band in conventional inorganic semiconductors. The most commonly used organic semiconductors can be broadly classified into small molecules and polymers. Small molecules are deposited by thermal evaporation whereas polymers are solution processed. Spincoating, screen printing, layer by layer deposition and printing are major solution processes. Inexpensive and low temperature processes make them ideal for large area applications. In addition, the low temperature processes make them compatible with plastic substrates.

Television introduced by Sony

Organic light emitting diode

There are five processes happening in an OLED. 1) Charge injection from the electrodes 2) Charge transport through the transport layers 3) Exciton formation 4) Exciton recombination and 5) Light emission. There are top emitting and bottom emitting structures for OLEDs. In a conventional bottom emitting diode, the anode should be transparent and should be able to inject holes into the adjacent layer(hole injection layer, HIL). The HOMO of this HIL and the work function of ITO should be matching to facilitate hole injection. Similarly the cathode should be a low work function metal to be able to inject electrons into the electron transport layer(ETL). The holes and electrons thus transported to the emissive layer(EML) form excitons which are short lived. They may recombine radiatively or nonradiatively. When they recombine radiatively, emission of a photon occurs. Only a small portion of the total photons thus generated escapes out of the OLED structure to provide the external emission. This is due to refractive index mismatch of adjacent layers, standing wave formation etc.

Both fluorescent and phosphorescent materials are being used as the emissive layer. Fluorescent molecules have a theoretical maximum efficiency, 25%. This is because out of the four excited state possibilities(one singlet and a triplet) only the excited singlet state corresponds to emission. However, phosphorescent devices make use of the triplets also and hence can have higher efficiency.

OLED displays

The huge success in realizing highly efficient red, green and blue OLEDs paved way for using this technology in displays. There are two types of OLED displays: 1)Passive matrix OLED (PMOLED) displays and 2) Active Matrix (AMOLED) displays. Both have anodes in the form of columns and cathodes in the form of rows. A OLED is placed at any intersection of a cathode and anode. The image is displayed by sequential scanning of rows in both cases. A usual frame rate is 100frames/s. Because of this fast scanning, though only one row is ON at any given point of time, the viewer feels like the whole display is ON. This is how PMOLED displays show an image. But as the resolution and size go up, the light that should be emitted by one row to keep this illusion alive also goes up. The present driver ICs have a limitation in supplying current to the pixels and also at high current densities the pixel degradation occurs. To surmount this problem, the idea of AMOLED was introduced. Here the scanning charges a capacitor which is associated to a transistor. The charged capacitor can keep the transistor ON which in turn keeps the pixel ON. So the pixel is ON as long as the capacitor can provide a biasing. Hence the pixels will be ON even after the row has been scanned. Before the capacitor is fully discharged, it is charged again by the next scanning. Thus large area displays with higher resolution can be addressed.

In the beginning there were at least 20 manufacturers of PMOLED displays. However the limitation in size reduced their popularity and the advent of AMOLED further reduced PMOLED's chances to survive as a viable display option. Samsung and LG are the largest AMOLED manufacturers, though it was Sony who introduced a television with AMOLED and thus proved the commercial viability.

In India, Samtel Center for Display Technologies jointly set up by Samtel Color Ltd and Indian Institute of Technology Kanpur has been doing pioneering work in this field. Commercial quality PMOLED displays have been fabricated and efforts are on to develop AMOLED displays.

OLED displays beat their counterparts in almost every performance parameter of displays viz. brightness, power consumption, the color gamut, contrast ratio, response time, form factor and weight. However the cost of OLED displays is still higher compared to LCD displays. But it is expected that the costs should come down with ramping up of production. Also, OLED seems to be the only means to achieve flexible and transparent displays. In fact flexible displays open up a myriad of applications which were unimaginable only a few years ago. Think about a display which you can fold and keep in your pocket! ■

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Bits, Qubits and Measurements of Information

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Quantum information science, a new branch of science since its birth in 1970s, has been an active area of research. This includes several aspects of computations, measurements etc. The main aim or motive behind the development of this theory is to obtain complete control over a single quantum system. Quantum information theory includes additional elements apart from the static and dynamic elements in classical information theory.

The key concept of information was brought into light in 1940s by the fundamental work of Claude Shannon. Shannon's information theory was a milestone in the world of science and communication. Even today, this theory is applied in different dimensions in different branches of communication and is now known as the classical information theory. Shannon's theory deals with classical information and the way it can be transmitted over channels. He developed the noiseless channel coding theorem which quantifies the physical quantities required to store output from an information source. He also developed the noisy channel coding theorem which quantifies the information that can be reliably transmitted over a noisy communication channel. Error correcting codes were developed to protect the information being sent.

With the development of quantum mechanics, a new question arised; can't information be stored and transmitted using a quantum media? Shannon's classical information theory was extended to answer this. This led to the quantum counter part of Shannon's theory with the finding that quantum states suited more efficiently than the classical states as a static resource for storing information and a dynamic resource for communication. Each and every element in classical information science has its quantum analogue; even the coding theorems by Shannon has its quantum counterpart by Schumacher. Quantum information shows a bizarre property of entanglement. Transmitting two classical bits of information by just one bit, otherwise called superdense coding is a major milestone in this field.

Bits and Qubits

Bit is the fundamental and indivisible unit of information in classical theory. It takes a state either 1 or 0. An analogous concept in quantum mechanics is the qubit. It is nothing more than a fancy name for a two level quantum system. It too takes the state either 'up' or 'down'. Surprisingly a qubit can also exist in a superposition state. Qubit can be illustrated as a two level atom, two spin states of an electron, polarisation states of a photon etc.

The state of a bit can be easily measured and determined, while that of a qubit cannot be exactly found. On measurement we get the qubit to be either in the state 'up' or in the state 'down' with corresponding probabilities. As probabilities must sum to 1, they are constrained by a normalisation condition.

Shannon Entropy as a measure of classical Information

Information being transmitted has to be quantified. Quantifying information can be done in several different ways. The amounts of correlations in the state of a system, the degree of entanglement etc are the various aspects used for quantifying information. Entropy is an important measure to quantify information. It defines the amount of uncertainty in the state of a physical system. Shannon's entropy gives a compression factor of the classical information that is being transmitted via a quantum channel.

Let X be a random variable. One way to quantify information extracted from a system was introduced by Shannon in 1948 – the Shannon entropy H(X), which quantifies the amount of information that we gain on knowing X or the uncertainty that we had about X before learning it. It is otherwise a measure of the information that we gain on an average from a system or the missing information from the fine grained state of a system. X can be a string of letters $X = (x_1, x_2 \ldots x_n)$. Each letter is statistically independent and x_i's occur with a priori probability p_i. Shannon's entropy associated with the probability distribution is

$$H(p_1, p_2 \ldots p_n) = -p_1 \log(p_1) - p_2 \log(p_2) - \ldots$$

This is Shannon's definition of entropy. Logarithms used here is of base 2. Logarithmic base is used as the unit of information. Shannon's entropy so defined has the same form as that of Boltzmann's entropy in statistical mechanics. The less probable a message, the higher is the information content.

Let n = 2.Then if $p_1 = p$, $p_2 = (1-p)$

Claude Shannon

Shannon's binary entropy $H_{bin}(p)$ or $H(p) = -p \log p - (1-p) \log (1-p)$.

When p = 0 or p = 1, H = 0 and when p = 1/2, H = 1, the maximum. Thus H (p) can be interpreted as the average information content of each letter in the message. Thus information is a measure of our apriori ignorance. In other words if we have a prior knowledge that we will receive x_1 with certainty (p=1), then in that case no information is gained. But if the 2 messages are equally probable, the prior ignorance is maximum. So H (1/2) = 1. We say we have received 1 unit of information or 1 bit. Shannon entropy is maximum when $p_1 = p_2 = \ldots p_n = 1/n$.

von Neumann entropy - a measure of quantum information

In quantum information theory, classical information is transmitted as quantum states or as quantum information. Schumacher in his quantum noiseless theorem states that the optimal compression is given by von Neumann entropy. Thus von Neumann entropy is the appropriate measure of quantum information just as Shannon entropy is of classical information. Rather than using state vector formalism, the density matrix formalism is used in quantum information theory as it is a natural framework for both open and composite systems. The quantum state is not represented by probability distribution like in the classical case but by density operators. All the quantities in Shannon's theory have its quantum analogue in von Neumann's theory.

The von Neumann entropy can also be interpreted as the amount of information that is missing from a state ρ. Thus it can be defined as

$S(\rho) = -\operatorname{tr}(\rho \log \rho)$, where ρ represents the density matrix. Logarithm used here is also of base 2.

Density matrix ρ describes an ensemble of quantum states, defined as any hermitian, positive, semi definite operator with unit trace.

If λ_i's are the eigen values of ρ, then

$$S(\rho) = -\lambda_1 \log \lambda_1 - \lambda_2 \log \lambda_2 - \ldots$$

We take 0log0=0 as in Shannon entropy. Some other properties are,

- In a d dimensional Hilbert space, a completely mixed state I/d has extremum entropy of log d.
- Quantum relative entropy between two states ρ and σ is

  $S(\rho||\sigma) = \operatorname{tr}(\rho \log \rho) - \operatorname{tr}(\rho \log \sigma)$.
- For a composite system AB in a pure state, S (A) = S (B).
- The joint entropy of a composite system is defined as

$$S(A, B) = -\operatorname{tr}(\rho^{AB} \log \rho^{AB}),$$

ρ^{AB} being the density matrix of the system AB.

Quantum mutual information is obtained from the above quantities as

$$S(A : B) = S(A) + S(B) - S(A, B)$$

Much information regarding the state of a system can be obtained from the above defined entropic quantities.

Now, when we measure a system, entropy behaves depending on the operation that is done on the system. If a projective measurement P_i takes ρ to ρ', then the entropy is increased but if the state is not changed on measurement, entropy remains the same. Like Shannon entropy, von Neumann entropy is also a concave function of its inputs. This means that uncertainty of a mixture of states is higher than the average uncertainty of the states.

Though the both entropic quantities H and S serve the same basic purpose, properties are different giving different consequences. Similar quantities in both the theories can be used to quantify various correlations in the system. Several measures of non classical correlations in a bipartite system can be obtained as the difference between the classical entropic quantities and the corresponding quantum entropic quantities. Nowadays this has become a potential area of research.

Thus entropy is a very useful tool to quantify information content in the state of a system. But if the information is quantum, then it is not accessible. One cannot make a copy of the information content as is done with classical information. This is well explained by the no-cloning theorem, which states that quantum mechanics does not allow unknown quantum states to be copied exactly. But if the two states are orthogonal, then this is violated. ■

von Neumann

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Hopf Bifurcation and Period Doubling in a Hollow Cathode Discharge

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Abstract

The experimental observation of two universal routes to chaos viz. Hopf bifurcation and period doubling route in a dc hollow cathode discharge is demonstrated. Quasi periodic oscillations and also a slight hysteresis in the bifurcation phenomena are also observed.

Introduction

The phenomena of order and chaos occurring in non-linear dissipative systems have been the subject of intense research in recent years [1]. Universal characteristics of chaos have been observed both in numerical simulations and in experimental situations viz. optics, hydrodynamic flow, optical bi-stability, electrical circuits etc. These studies have demonstrated transitions from order to chaos through various routes [2]. Electrical gas discharge is a typical non-linear dynamical system and is an interesting medium to test these numerical characteristics of chaos [3,4].

The oscillatory phenomena in discharges have a long history, moving striations and oscillations have been detected in electric discharges under various experimental conditions. Moving striations and oscillations are always erratic and regular and are different manifestations due to atomic processes that are taking place in the discharge. These oscillations can be observed by monitoring the discharge voltage, current or the light emitted from the plasma. The characteristics of oscillations depend on the nature of the gas, total pressure, cell geometry, external electric parameters etc. This article demonstrates the experimental observation two universal routes to chaos viz. Hopf bifurcation and period doubling route in a dc electric discharge.

Experimental setup

Schematic diagram of the experimental setup is shown in

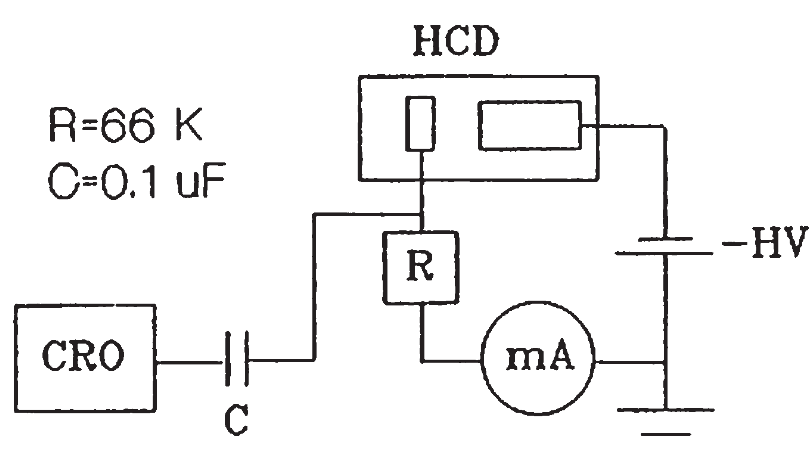

Figure 1. Experimental setup

the figure 1. A commercial hollow cathode discharge lamp with molybdenum cathode filled with neon buffer gas is operated at low current. The discharge is maintained by applying a ripple free dc voltage using a highly regulated power supply. The discharge current is limited using a resistance which is in series with the power supply. The output signal across the resistance is monitored using a CRO with 50 ohm termination by blocking dc voltage using a capacitor. In the non-oscillating state the output is only a random noise which was almost at zero level. The current which is the control parameter in the plasma dynamics is slowly increased. By monitoring the temporal evolution of the signal, different states can be observed under various experimental conditions.

Self generated oscillations

When a voltage is applied to the discharge cell energetic electrons ejected from the cathode will be accelerated towards the anode. These electrons periodically ionize the background neutral gas atoms and create plasma between the electrodes. The two processes viz. the generation of primary electrons and the production of plasma are strongly coupled. The primary electrons ionize the gas and sustain the plasma while the plasma reduces negative space charge and enhances electron emission. By varying the discharge parameters one can control this coupling or the feed back processes resulting the plasma dynamics unstable and the current oscillations may occur when the plasma potential is unstable.

Hopf Bifurcation

The representation of the amplitude of oscillation as a function of control parameter (here it is discharge current) constitute a bifurcation diagram. In Hopf bifurcation the limit cycle is created with zero amplitude at the bifurcation point and the amplitude of the limit cycle increases as the control parameter is increased beyond the bifurcation point. When the current is gradually increased in the presence of discharge, it is found that the self generated oscillations starts at the current 2.4mA. As the current is further increased quasi-periodic oscillations are also observed in the region A and B. In the figure 2, the bifurcation diagram in which the amplitude of oscillation as a function of discharge current is given. The frequency of oscillation is also

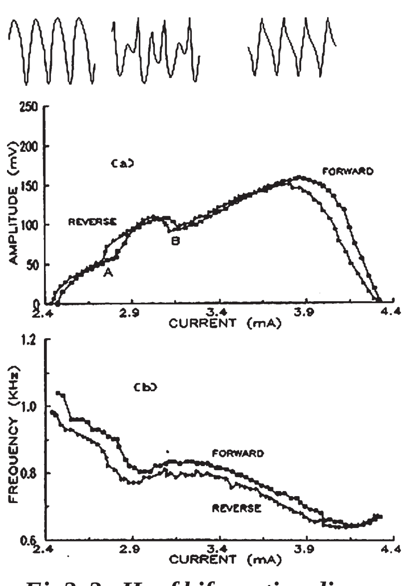

Fig2, 3 : Hopf bifurcation diagram in plasma dynamics in a Mo/Ne hollow cathode lamp with discharge current as the control parameter.
Variation in (a) amplitude and (b) frequency of oscillations with discharge current.
Shape of oscillations for different regions is also shown.

shown in the figure. In the region A and B a quasi periodic oscillation in the bifurcation phenomena, and also a slight hysteresis are observed.

Period doubling

When the discharge current is varied keeping all the parameters constant the system bifurcates to a period doubling state and the temporal evolution is very different from the periodic oscillations. When the discharge starts just a stationary dc value is observed, then a self generated oscillation appears which is superimposed to the dc level. By lowering the current in the circuit it is possible to see a very clear period doubling sequence as displayed in the figure 3. The temporal evolution of the signal shows a period doubling route. The power spectrum and the phase space plot analysis of the CRO traces of the oscillatory pattern confirm the existence of the period doubling route to chaos.

Conclusions

The observation of two universal routes to chaos viz. Hopf bifurcation and period doubling route in a dc hollow cathode discharge is demonstrated.

Supports from UGC (New Delhi), DCE (Trivandrum) acknowledged. ■

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Physics of Protein Folding

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Proteins are the most versatile macromolecules in living systems and perform an amazingly wide variety of functions. Some examples of the functions they perform are transport of different molecules (ex. oxygen), transmission of signals between cells and organs, control passage of molecules through cell membranes, form building blocks of several biological structures, provide immune protection, etc. The capability of proteins to perform these functions is critically dependent on the unique three-dimensional conformation the linear amino acid chain adopts or the natively folded structure of the protein. Since properly folded proteins are involved in performing a wide variety of functions, there are serious consequences when proteins do not fold correctly. Several well-known diseases such as Alzheimer's, Mad Cow, Parkinson's, types of cancers, etc are due to mis-folded and/ or aggregated proteins. Hence advancements in the field of Medicine are also dependent on our understanding of protein science. In spite of more than 50 years of research on the protein folding problem the answer still eludes us and it remains one of the most interesting yet unanswered scientific questions. From an academic standpoint, protein folding has developed into a strong multidisciplinary field of research involving biology, biochemistry, physics, computer simulations, etc.

Proteins are composed of linear chains of amino acids bonded together by peptide bonds. Amino acids (structure shown in Fig. 1) are the structural building blocks of proteins. In general 20 different standard amino acids are found in proteins, the side-chain (denoted by 'R' in Fig. 1) being unique for each of the 20 amino acids. The linear chain of amino acids is formed by peptide bonds formed between the carboxyl group (COOH) and amino group (NH_2) of neighboring amino acids. Proteins have a wide variety of sizes – small proteins are formed of about 20-30 amino acids with molecular weight of 2000 – 3000 Daltons to large proteins containing more than 1000 amino acids (molecular weight greater than 100,000 Daltons). The specific sequence of amino acids in the linear chain of a particular protein defines its **primary structure**. Two higher levels of structural organization are observed in proteins – secondary and tertiary structure. **Secondary structure** is characterized by a certain number of consecutive amino acids in the chain adopting specific orientations that result in the formation of different secondary structural elements such as á-helices and â-sheets. The unique orientation of these secondary structural elements such as á-helices and â-sheets with respect to each other

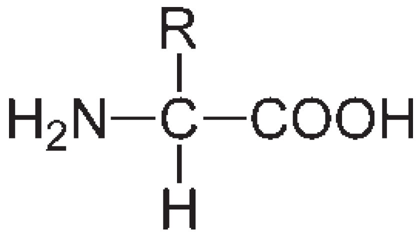

Figure 1.
Structure of an individual amino acid

resulting in the formation of the unique three-dimensional structure of the protein is referred to as the **tertiary structure**. Formation of the native three-dimensional protein structure from an essentially unstructured linear chain of amino acids (also referred to as the unfolded state) is referred to as protein folding. Figure 2 shows a schematic view of an unfolded and folded protein molecule. The linear amino acid chain of a protein molecule is synthesized within cells and it may be hypothesized that some specific cellular machinery may be involved in converting the linear amino acid chain into its three dimensional native structure. However, since the 1950s it has been shown in several experiments that this is not the case and that proteins are, in general, capable of folding to their native state by themselves. In other words, all the information required for folding of a protein to its native state is encoded within the primary structure or the sequence of amino acids. Hence the protein folding problem can be defined as the prediction of the native folded structure based on the amino acid sequence.

Experimentally the three-dimensional structure of a protein can be obtained at high resolution by techniques such as crystallography and nuclear magnetic resonance (both physics based techniques). Though significant advances have been made in development of both techniques (synchrotron based diffraction, high resolution NMR, etc.) not many proteins are still amenable to structure determination using these methods, while methods for amino acid sequence determination have become more routine. Hence prediction of the three-dimensional protein structure from only the knowledge of amino acid sequence (basically solving the protein folding problem) assumes even higher significance.

As mentioned earlier, it has been accepted since the 1950s that all the information required for a protein molecule to fold to its native state is encoded within its amino acid sequence. Understanding how this happens based on first principles and the laws of physics is the objective of *ab initio* protein folding studies. At the core of these ab initio studies is the design of an energy function (Hamiltonian) that adequately describes all interactions between different components in the system (all individual atoms of the protein in an aqueous environment). Laws of classical mechanics can be used to arrive at the time-course behavior of such a system once the Hamiltonian is defined. Thermodynamic quantities of interest at equilibrium can also be obtained from standard approaches developed in

Figure 2. Schematic showing folding of an unfolded amino acid chain to the folded native structure.

statistical mechanics (partition functions defined in statistical mechanics). The challenge of applying these principles to the folding problem lies in the enormous complexity of the system – a small protein (~100 amino acids) contains of the order of thousands of atoms interacting among themselves and with the water molecules surrounding them. Hence defining the energy functions or the partition functions for these systems are particularly challenging and solutions to these problems are possible only through computational approaches. Significant advances in folding studies have been made over the last 20 years or so with the availability of high computing power. An alternate approach to the protein folding problem is also the development of knowledge based approaches as opposed to the above mentioned ab-inito approaches. In the knowledge based approaches, large amounts of data from experimentally determined protein structures of known amino acid sequences are used for predicting the structure of a new amino acid sequence.

Experimental studies on protein folding also rely heavily on biophysical techniques such as fluorescence spectroscopy, circular dichroism, NMR, scattering techniques etc. to name a few. Experimental studies on folding have shown that the folded state is only marginally stable – free energy difference between the folded and unfolded state is only of the order of 5-10 kcal/mole (compare to RT of 0.6 kcal/mole at 25^{o}C). However, if we split the contribution to this free energy difference into enthalpic and entropic parts, it can be seen that the folded state is enthalpically favored by hundreds of kcals due to all the attractive interactions in the folded state whereas entropically the native state is highly unfavoured compared to the unfolded state. Both experimental and theoretical/computational approaches to understanding the protein folding problem continue to be a very active area of interdisciplinary research.

This short article is a very brief attempt to introduce the protein folding problem and its connection to physics. ■

APT Team with Prof. C. Vijayan (IIT, Chennai), Prof. Ramachandran Thekkedath (Vice Chanceller, CUSAT) and Prof. Godfrey Louis (Pro-Vice Chanceller, CUSAT).

Adventures with Physics Teaching and Learning - Public Lecture on 17-03-2012, Physics Auditorium, CUSAT.

Synchronization in Coupled Oscillators - Music of the Universe

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Synchronization as an emerging phenomenon of a population of dynamically interacting units has fascinated human beings from ancestral times. Synchronization processes are ubiquitous in nature and play a very important role in many different areas such as physics, biology, ecology, climatology, sociology, technology, or even in arts. It is known that synchrony is rooted in human life from the metabolic processes in our cells to the highest cognitive tasks we perform as a group of individuals.

In 1665, the mathematician and physicist, inventor of pendulum clock, C. Huygens, discovered synchronization in two pendulum clocks suspended side by side by each other. The pendulum clocks swung with exactly the same frequency and 180^0 out of phase. When the pendula were disturbed, the antiphase state was restored within half an hour and persisted indefinitely. From that time on, the phenomenon became the focus of scientists.

There is growing evidence that at the heart of every synchronous pattern in nature is a "coupled oscillator". Oscillation is the repetitive variation, typically over time, of some measure about a central value often a point of equilibrium or between two or more different states." Examples of oscillation include swinging pendulums, heart beats, and tidal rhythms. An oscillator is a device that causes oscillations to take place driven electrically, chemically or behaviorally etc. A coupled oscillator is a series of single oscillators that, with time, cause each other to act or synchronize to a rhythm.

Nature's coupled oscillators include circadian clocks, pacemaker cells in heart and nervous system, collective oscillations of pancreatic beta cells, synchronously flashing fireflies, crickets that chirp in unison, human menstrual synchronization etc.

Fireflies

In the animal world, groups of Southeast Asian fireflies provide a spectacular example of coupled oscillators and synchronization. Along the tidal rivers of Malaysia, Thailand and New guinea, thousands of fireflies congregate in trees at night and flash on and off in unison. When they first arrive, their flickering are uncoordinated. But as the night goes on, they build up the rhythm until eventually whole treefuls pulsate in silent concert. Watching synchronous blinking of fireflies has boomed into an industry at

Kuala Selangor firefly park (Malaysia), see www.fireflypark.com

The Ciracadian clock

The Greek word "circadian" means "about" daily. Intuitively, we are all familiar with our own biological clock and, at least in general terms, the rhythm of nature. Our own internal circadian pacemaker is a group of cells that act as a chronometer to keep us in synchrony with our world. That pacemaker is a chemically driven coupled oscillator. It is known our body's synchrony operates at three different levels. First, cells within an organ are mutually synchronized much like a coupled oscillator. Second, synchrony occurs between organs keeping the same periodicity even though function may vary. The third level of synchronization is between our body and the world around us.

Steven Strogatz, Professor at MIT, who have made extensive studies on synchronization in coupled oscillators especially in biological oscillators rightly comments in his famous book "Synchronization- The emerging science of spontaneous order"

"At the heart of the universe is a steady, insistent beat: the sound of cycles in synchronization. It pervades nature at every scale from the nucleus to the cosmos. Every night along the tidal rivers of Malaysia, thousands of fireflies congregate in the mangroves and flash in unison, without any leader or cue from the environment. Trillions of electrons march in lockstep in a superconductor, enabling electricity to flow through it with zero resistance. In the solar system, gravitational synchrony can eject huge boulders out of the asteroid belt and toward Earth; the cataclysmic impact of one such meteor is thought to have killed the dinosaurs. Even our bodies are symphonies of rhythm, kept alive by the relentless, coordinated firing of thousands of pacemaker cells in our hearts. In every case, these feats of synchrony occur spontaneously, almost as if nature has an eerie yearning for order" ■

APT - Talent Search Examination 2011
- A Report

Ms. Sindu Jones
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Academy of Physics Teachers (APT) is a professional body of college and University teachers. Apart from other activities like seminars, workshops etc, APT conducts Talent Search examination every year for degree students who has taken Physics as their core subject in Kerala. The objective of conducting Talent Search examination is to identify and groom the aspirants of Physics. For doing so, an examination co-coordinator is chosen for the conduct of the examination. The students are judged by three different modes. The first phase comprises of 75 multiple choice questions in Physics. A screening is done at this stage i.e. those who obtain 35 or above marks in the first phase are Qualified into the second phase which is a descriptive type question answer. The marks obtained from the two papers are added and tabulated to find the first 25 toppers. In the final round these 25 students are interviewed to find three toppers.

The written part of the examination was conducted on 24th September 2011 in 29 different centers all over Kerala Of the 934 students 840 students appeared for the examination. On this occasion the APT likes to congratulate Dr Devadas of MG College, Iritty, for presenting the highest number of (126) candidates for the Talent Search Examination. The interview was conducted for the top 26 candidates of the examination conducted on 24th September 2011. The interview was conducted on 4th Feb 2012 at CUSAT, Kochi from 10:00 am onwards till 5:00 pm by eminent Professors of different colleges and universities. The interview board comprised of Prof Dr. Ramesh Babu [CUSAT], Dr Jayaraj [CUSAT], Dr Gopalakrishna Panickar [NSS College, Changnacherry], Dr Suresh Vettor [St Dominics College, Kanjirapally], Dr Titus K Mathew [CUSAT], Sri Shaju, Smt Sindu Jones [Baselius College, Kottayam]. The result of the interview along with the examination marks are tabulated below with their ranks.

Thus Sri **Nijin Lal C K** of Govt College Madapally was declared the topper of the Talent Search Examination. The Second prize went to **Vaisakh C** P of St Josephs College, Devagiri and the Third Rank was bagged by **Sreejith P K** of Malabar Christian College, Kozhikode.

The prizes for the first three Rank holders and certificates to the first 26 candidates was distributed on 17th of March 2012 at a function in CUSAT. The chief guest of the ceremony was Dr C Vijayan, IIT Chennai. He delivered a talk on Nanotechnology.

The executive members of the Talent Search Examination is thankful to all the regional coordinators, APT members and all the authorities of the colleges, who had taken great pains to conduct the examination enthusiastically. Special gratitude are for the office staff of Department of Physics, CUSAT for their services rendered in conducting the Interview and valedictory function. ■

Academy of Physics Teachers, Kerala
- A Report of Activities 2010-12

Dr. P.J. Kurian
General Secretary (2010-12)
Academy of Physics Teachers, Kerala

2010-2011

The annual general body meeting of the Academy of Physics Teachers, Kerala started at 2pm on 31/1/2011. The Vice-President of the Academy Prof. G. Geetha Presided over the function. Dr. P.J. Kurian, Secretary presented the report of the Academy and the General Body passed the same. Dr. Santhosh P Kuruvilla, Treasurer presented the audited accounts of the year and it was passed. Prof. G. Geetha delivered the presidential address. The IYE 2009 DVD was released at the meeting. Its convenor Dr. Jose Mathew made a speech and then vice-president Prof. G. Geetha gave the DVD to senior member Prof. P.T. Kurian.

The meeting unanimously elected Prof. Sindu James of Baselius College, Kottayam as the new state level coordinator of the Talent Search Examination 2011. Prof. P.T. Kurian spoke at the meeting. He urged the Association to encourage the young members. It was decided that APTTunes, the journal of the APT, should be published quarterly every year. Dr. Suresh V Vettoor suggested that more colleges, should be involved in the activities of the Academy. Dr. P.S. Raghupathy suggested that a list of resource persons should be prepared from members of APT to deliver lectures in various topics. The meeting decided that the life membership fee should be fixed at Rs.1000/-. The meeting concluded at 3.30 pm.

Public lecture of Nobel laureate and prize distribution ceremony

The winners of the APT Talent Search Examination 2010 were facilitated in a special meeting organised by the APT at 11 am in the School of Pure and Applied Physics auditorium. The function was presided over by Prof. G Geetha Vice-President of the Academy of Physics Teachers Kerala. Dr. P.J Kurian secretary of the academy welcomed the gathering. Prof. Rajan Gurukkal Hon. Vice-Chancelor of the MG University Kottayam inaugurated the function. Prof.

N.V. Unnikrishnan, Professor and Director of the School of Pure and Applied Physics, MG University delivered felicitation speech at the function. Dr. K Indulekha of SPAP, MG University introduced the chief guest, Physics Nobel laureate Prof. Sir. Anthony J Leggett.

Prof. Sir. Anthony J Leggett distributed the certificates, mementos, books and cash prizes. Prof. Leggett delivered a public lecture in the topic "Why can't time run backward ?" at the function. It was an inspiring lecture that captivated the audience.

The ever rolling trophy for the first prize winning college was given to S.H. College, Thevara, Ernakulam. Let me also thank the Co-ordinator for TSE 2010 Prof. G. Harikrishnan, Govt. College, Madappally for his excellent work.

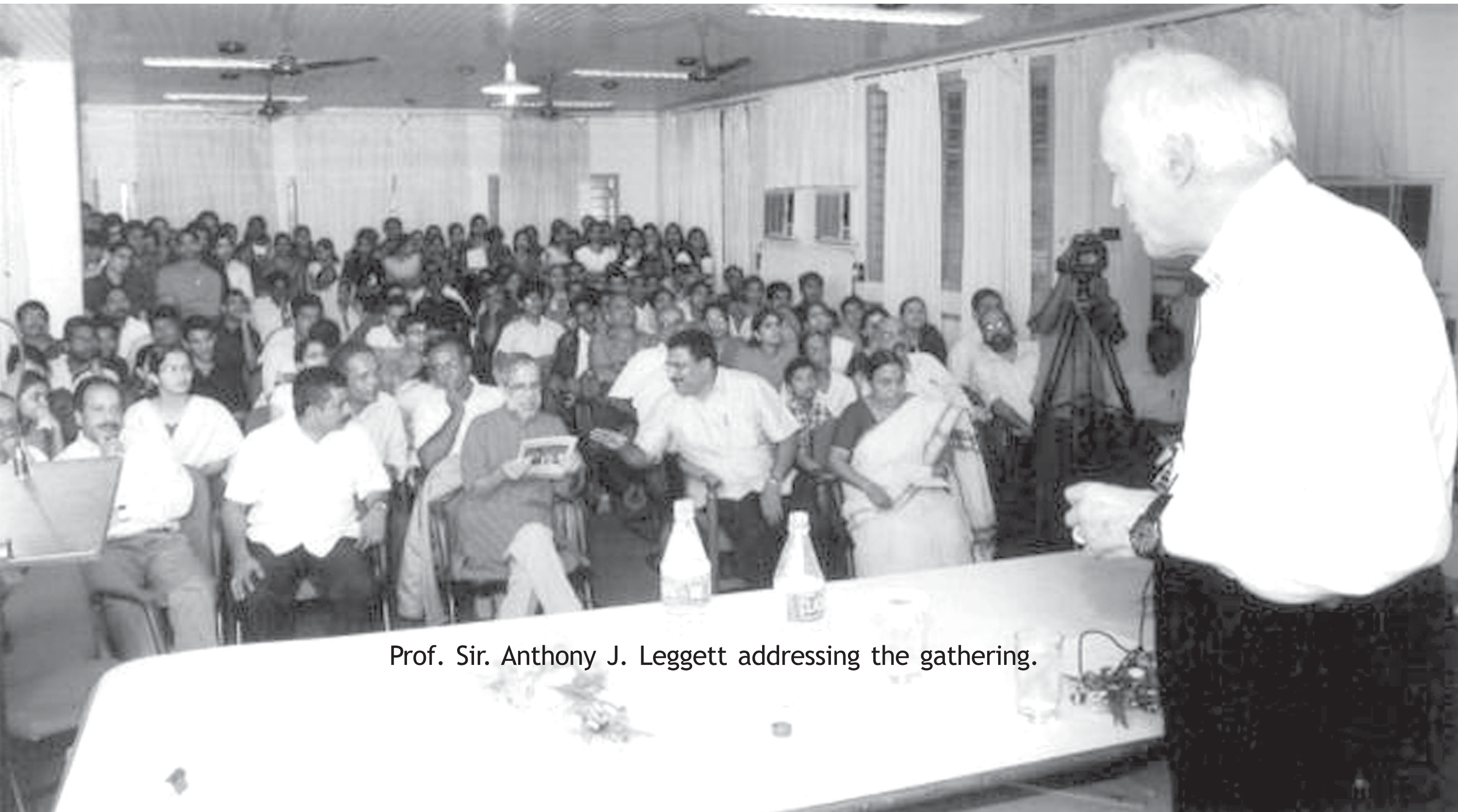
2011-2012

The annual general body meeting of the Academy was held on 17/03/2012 at Dept. of Physics, CUSAT, Kochi at 2 pm. The president Prof. Godfrey Louis presided over the function. Dr. P.J. Kurian, Secretary presented the Academy activities report of the past one year. The various Activities of the Academy of the last year were reported in the general body meeting. The Co-ordinator of the TSE-2011, Dr. Sindhu Jones of Baselious College, Kottayam presented the report. The copy of the report is enclosed.

The treasurer of the Academy Dr. Santhosh Potharay presented the audited accounts, of the previous year. The copy of account statement is enclosed. The General body passed the account statement of the previous year.

Elections for the office bearers of the year 2012-2014 were held and Prof.Anatharaman Head, CUSAT, acted as the Returning Officer. The names of new office bearers of the Academy are given on another page of this journal.

The annual function of the Academy was inaugurated by Prof. Ramachandran Thekkedath, V.C. of CUSAT. Prof. Godfrey Louis, President of the Academy presided over the function. Dr. P.J. Kurian secretary of the Academy welcomed the gathering. The Chief Guest Prof. C. Vijayan, I.I.T. Chennai was introduced by Dr.Jayaraj of CUSAT. Prof. C. Vijayan has presented a talk on "Adventures with Physics Teaching and Leavening". The talk was highly thought provoking and well received. Dr. Santhosh Potharay expressed the vote of thanks. During the function the prizes for the T.S.E. Winners and Co-ordinators were distributed. The ever rolling trophy for the first prize winning college was given to Govt. College, Madappally, Kozhikode. The General body meeting concluded at 3:30 pm. ■



Prof. Sir. Anthony J. Leggett addressing the gathering.

New Horizons in Magnetic Materials Research

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Magnetism and magnetic materials have attracted human beings for a very long time. The history of magnetism dates back to the year 1600 when W. Gilbert published his magnum opus 'De magnete'. The topic of magnetism became interesting because of the magnetic effects of electric currents and a variety of magnetic materials themselves. The practical exploitation of the former has resulted in a large number of devices which are indispensable for us today. To name a few are the motors and the generators. The development in the field of magnetism in materials started as a curiosity to understand the new and exciting phenomenon, but soon it was realized that it represents a huge reservoir for many practical materials. In this context, the miracle material was the magnetite, Fe_3O_4 which is known as the ferrite. Ferrites now represent a large class of magnetic materials. In a way, the history of the magnetic materials research is synonymous with the development of the ferrites, both in terms of fundamental studies and their commercial application potential.

These days, the magnetic materials find applications in a whole variety of fields/ applications. In addition to the ferrites, a large number of ceramic and metallic materials have been identified and developed for these applications. Going by the general classification of magnetic materials as ordered vs. paramagnetic, most of the applications find their origin in the magnetically ordered materials. This includes ferromagnetic and ferrimagnetic materials. The latter possesses antiferromagnetic coupling at the atomic scale, but shows ferromagnetic-like properties at the bulk scale. The temperature below which these materials retain their magnetic order is called the Curie temperature (T_C). For most of the applications, therefore, the Curie temperature must be above room temperature.

As mentioned earlier, one of the broad classifications of magnetic materials is ceramic vs. metallic. The first one comprises of electrical insulators or poor conductors, whereas the second one represents conducting materials. Since in any application, energy loss is an issue, only ceramic materials are suitable for high frequency applications like communication. This is because of the fact that for conducting magnets, the eddy current loss associated with the high frequency, is quite high and undesirable. Ferrites for various compositions and in various crystalline forms find extensive applications in communication and related applications. I would like to mention here that one should not confuse the eddy current loss with the hysteresis loss, which is due to the cycling of the magnetic field. The hysteresis loss is mainly determined by the magnetic anisotropy of the material.

The other major class of materials is the intermetallic compounds formed between the rare earth elements and transitions metals (Fe/Co/Ni). These alloys have the advantage that they are mostly ferromagnetic with large saturation magnetization, Curie temperature and magnetic anisotropy. These alloys constitute the bulk of the permanent magnets that we use in various devices today. For example, a car uses several pieces of these magnets for various applications. The most important difference between these permanent magnetic materials and the ferrites mentioned earlier is that the hysteresis is quite large in the former. Because of these reasons, the permanent magnet materials have very high coercivity and remanence. Such materials are generally called the hard magnetic materials. On the other hand, the materials with very small coercivity are called soft magnetic materials. They are characterized by large permeability and are central components in devices where large flux is needed. Transformer core is the best example wherein one uses soft materials.

Historically, the other major application of magnetic materials has been in magnetic recording, a field which gets revolutionized every decade or so with the new breakthroughs in magnetic materials research. Magnetic recording is one of the most popular and wide-spread applications of magnetic materials today. The very existence of many devices critically depends on these materials. For magnetic recording applications, usually one uses materials in thin film for multi-layer form. A large number of ferrites thin films and metallic thin films have been in use for this application. The path-breaking discovery of spintronics has added a new dimension to the field of magnetic recording. In the conventional electronic, one employs the charge of the electron and its manipulation with the help of an electric field. But in spintronics, one has the additional degree of freedom namely the spin of the electron, which can be controlled by a magnetic field. The field of spintronics is still growing and is supplemented with the new developments in magnetic thin film and nano materials research. Magnetic semiconductors is an important field today because of the possibility of getting good spintronic materials and devices. In this context, there is a strong demand for the so called half metallic ferromagnets, which have one type of spins behaving like a metal and the other type of spins behaving like a semiconductor or an insulator with a gap in their band structure. Such materials are expected to show large spin polarization (excess of one type of spins for conduction) thereby enabling one to get a ‘spin-up’ or a ‘spin-down’ current. If such materials are available at room temperature, it will be of great advantage for many applications of spintronics.

Magnetic sensors and actuators form another important area of application of magnetic materials. Magnetic materials are being used to measure parameters such as magnetic field, temperature and pressure. The classic example in this category is the use of magnetostriction. This is the phenomenon in which the dimensions of a ferromagnetic material change when an external magnetic field is applied. By applying a time varying magnetic field, one can set a magnetic rod into vibration, thereby converting the electrical/magnetic energy into mechanical energy. This principle can be used for energy conversion or sensing. The so-called magnetostrictive transducers are being extensively used for SONAR (SOund Navigation And Ranging) applications in submarines etc. The magnetostrictive transducers have many advantages over the piezoelectricity-driven devices namely the PZT (lead zirconium titanate) devices. Rare earth-transition metal intermetallics play a vital role in this application.

A relatively new application of magnetic materials is in magnetic cooling. This is based on the principle of adiabatic demagnetization of a magnetic material wherein the magnetic entropy of the solid is manipulated by changing the applied field. This gives rise to desired changes in the temperature, thereby enabling one to use this technique for cooling (refrigeration) or heating (heat pumps) applications. The most important advantage of magnetic refrigerators is that they are eco-friendly in nature. These are being projected as superior to the existing conventional gas based refrigerators. The efficiency, compactness and adaptability of magnetic refrigerators have given the field of magnetic cooling a separate and recognized identity. Both ceramic as well as metallic materials are being considered as magnetic refrigerants. Though ferromagnetic materials are used as refrigerants for sub room temperature applications, paramagnetic materials find applications below 1 K, typically in the milli Kelvin range.

Like the exploitation of the change in the specific heat of a material under the influence of a magnetic field for magnetic cooling purposes, one can also look for a change in the electrical resistivity. This change can be so huge in systems where an insulating magnetic material transforms to a metallic ferromagnet, under the application of an external/internal field. In this case, the change in the resistivity is so large that often this phenomenon is called colossal magnetoresistance (CMR). Several transition metal oxides are known to undergo this kind of a field-induced insulator to metal transition, resulting in CMR. In addition to CMR, there are a large number of metallic and ceramic (both in bulk and thin film form) systems which show large magnetoresistance suitable for applications like field sensing.

A large number of magnetic materials are being prepared in amorphous form because of their applications related to soft materials. They are also important in the synthesis of nano-structured materials by giving proper heat treatments. Magneto- impedance and magneto-optics are two other fields which are of great importance today. Magneto-impedance refers to the change in the impedence of a magnetic material when an alternating current circulates over the surface. The change in the penetration dept of the ac current leads to a change in the impedence. Giant magneto-impedance (GMI) exhibited by some materials enable them to be used in GMI sensors. Many smart materials using GMI materials are being designed with the view of multifunctional applications. Magneto-optics deals with the change in the polarization of light by a magnetic field, either internal or external. This is of great use in magnetic recording.

Nano/Bio/Molecular magnetism is a field which has been attracting a lot of attention of researchers all over the globe. The fact that the physical properties change drastically as the dimensions are reduced has resulted in designing a large number of new particulate and molecular systems. It is even more interesting because of the realization that many of these systems can be used for medical, sensing, recording, cooling applications etc. Targeted drug delivery, especially for cancer treatment (magnetic hyperthemia) is a very important field of research in medicine today. Magnetic resonance imaging is another field which depends quite a lot on the development of nanomagnetic materials. Furthermore, many potential systems/devices are being developed by integrating the soft and hard magnetic phases comprising of a nano composite. For example, the latest entry into the new generation permanent magnets is known as exchange spring magnet, which is essentially a nano composite system.

One cannot wind up any discussion on novel magnetic materials without mentioning about another recent and exciting discovery, i.e. that of multiferroic materials. The properties of these materials can be tuned by both electric field (as in the case of a ferroelectric material) and by a magnetic field (as in a magnetic material). These materials are expected to play a major role in magneto-electronic devices which are of great application potential. A large number of magnetic oxides are expected to be identified as good multiferroic materials.

The research and the interest in magnetic materials is not just confined to the solid state alone. The magnetism in the liquid state is best represented by Ferrofluids, which is yet another field of great current interest. These are nano scale colloidal suspensions of ferro/ferri magnetic particles. They have largely varying refractive, viscous, micromagnetic properties, which enable them to be used in a large number of engineering applications. Controlling the properties of a ferrofluid with the help of an applied magnetic field is the key to this class of systems.

Finally, the drive and motivation for magnetic materials research, as in any other field, are (i) the quest to understand the finer details of this intriguing phenomenon in various systems and (ii) search for novel materials suitable for various applications. In this context, topics such as computational magnetism, micromagnetism, band theoretical studies etc. have also become quite important and necessary. ■

Global Water Challenge and Role of Nanotechnology

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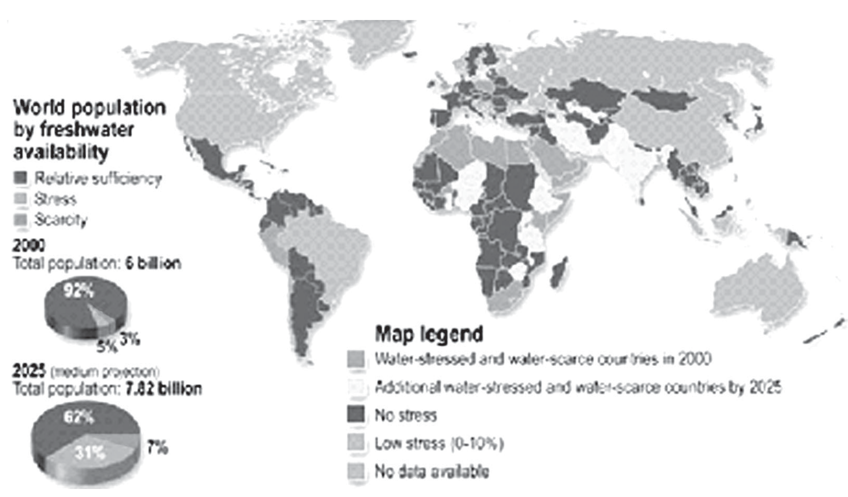
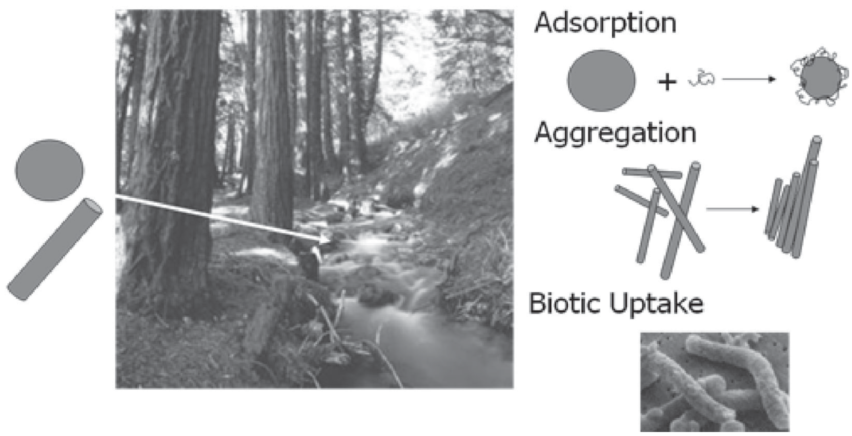
There is a common saying that one of the ways to become a millionaire is to discover a way to purify dirty water. Is this a big issue? Great visionary, Nobel Laureate Prof. Richard Smalley, during his famous talk in MRS meeting, Boston 2004 prioritized water as the second most important problem, just after energy, which the globe is going to face in the near future. Purification of water needs energy, but generation of any forms of energy needs water to a great extend; in other words they are interconnected.

Two third of the globe is covered with water, but 97% of this is in sea and it is out of possible usage for drinking or agriculture. From the rest, 2.5% is underground (deep earth or beneath icebergs) and hence only 0.5% is the usable water content in the globe. This 0.5% of water is facing issues like various kinds of contamination and pollution. But the demand for fresh water is increasing day by day. According to World Health Organization, 1 billion people do not have access to clean piped water. To make it worse, global population is going to increase from seven billion to nine billion in the next 50 years. If we consider the case of last century, global population quadrupled while the world water demand increased seven fold. Nevertheless a sustainable economy demands the sustainability in water balance, and it needs to be achieved by all developed or developing countries.

Statistical studies indicate that regarding the water sustainability, India's position on the globe is also not safe. How we can address the scarcity of water? Various steps can be undertaken such as



World fresh water availability and population. This result is based on the studies reported in Nature (2010) and Science (2006) magazines.



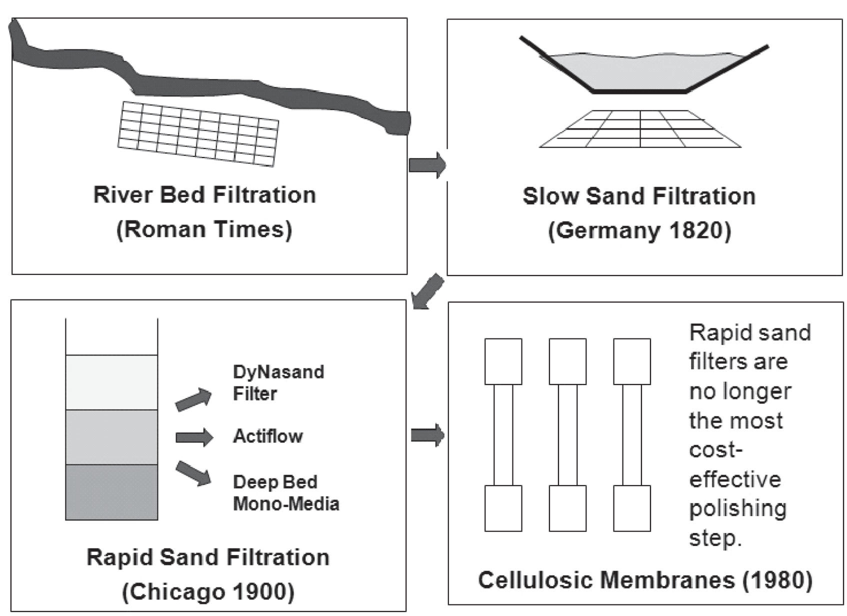
A natural water resource is pure at its best without the human interference. The adsorption, aggregation and biotic uptakes are taking places at various stages using sands, gravels and various roots of trees. We can take some these ideas to create artificial water purification systems.

water conservation, repair infrastructures (like ponds, wells etc.), improve water catchment areas, make good water distribution systems etc., but it is proven that they can only achieve a small fraction of the total water requirement. The only avenues for increasing water supply beyond what is available from the hydrological cycle are sea water desalination and waste water treatment and reuse. However, they require higher energy for treatments. For example sea water treatment requires at least 3-4 times energy than conventional water treatments. Highly effective, low cost, robust technologies for desalination and waste water treatment are needed and also those techniques must have minimal impact on the environment. Most of the Gulf-countries use thermal treatment for sea water desalination, but it consumes both thermal and electrical energy at the same time and produces a lot of greenhouse gases. Another challenge in water treatment is that method depends on the type of water to be treated and end use of the water. Water contaminations can be different from region to region around the globe and there is no 'universal system' to purify water. This also reveals the importance of region wise studies on the purification of water. Water treatments also depend on the end use. For example, drinking water needs the removal of organic and heavy metal ions (they vary in nature from place to place) along with the salts, while agriculture water needs complete removal of elements like boron and chlorides. Moreover, the usage of plastic bottle water has increased drastically over the past decade. In order to find better solutions, we need to understand the present scenario of water research.

We can never achieve the perfection of 'Mother Nature'. She has her own ways to balance the ecosystems, and what we can do is to mimic those techniques to our best level using the state of the art technologies.

Water purification is not a new topic. It was there before "germ theory of diseases" by Louis Pasteur. But there happened an evolution in water filtration technology. The old low efficiency river bed filtration technology in the Roman era has changed into polymer based highly efficient membrane technology.

How to stop contaminants in water? Basic water treatment contains 4 steps; coagulation/flocculation, sedimentation, filtration and disinfection. During



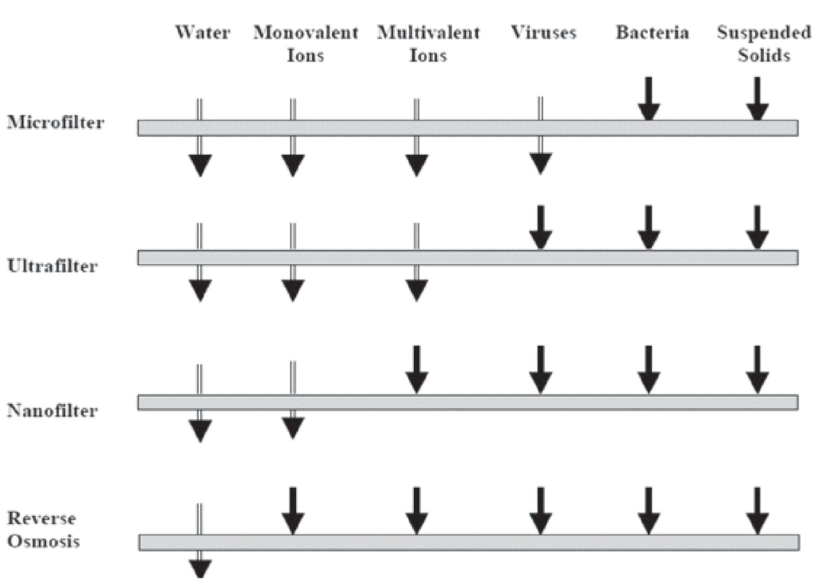
Evolution of water treatment technology

coagulation chemicals are added to water to form tiny sticky particles which will attract small particles. Flocculation refers to water treatment processes that coagulate smaller particles into larger particles which later settles down. These need to be removed using filters. We need to use good filters and filter pore size is the key factor determining the type of contaminants it can stop. Pouring water through sand, gravel or charcoal are simple inexpensive techniques for cleaning water. Various amorphous forms of carbon were identified as versatile adsorbents from age old times. But these techniques cannot stop small pollutants like bacteria, viruses, industrial pollutants, agriculture pollutants and salt. Hence the need for different membranes for water treatment. The filter membranes can be classified according to their size of the pores. From the chart (figure 4) we can infer that all techniques need energy (in the form of operating pressure) and out of various methods reverse osmosis is the only one technique which can remove almost all kinds of contaminants. To date, the only successful treatment for sea water desalination is Reverse Osmosis (RO).

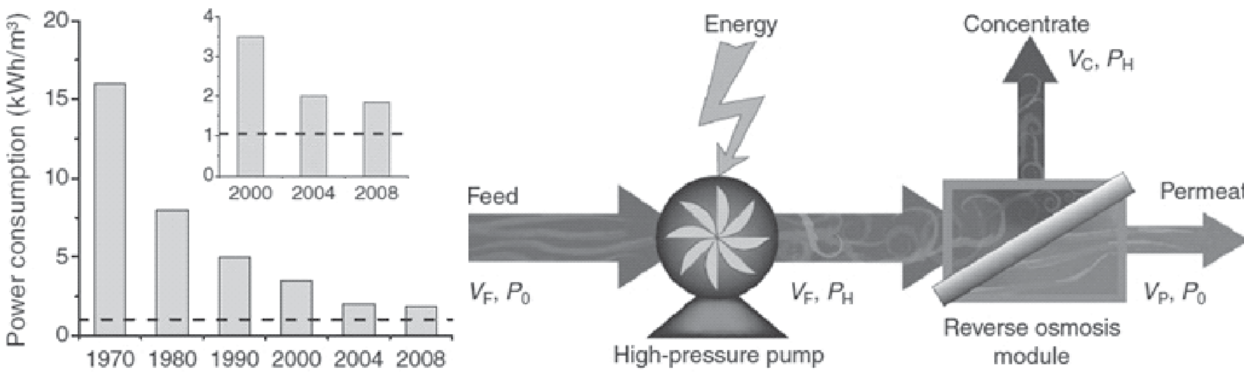
Osmosis is a natural process that moves water across a semipermeable membrane from an area of greater concentration to lesser concentration until the concentrations become equal. In the mid of last century, researchers from University of California developed a reverse process by applying pressure, and then they could purify sea water. High pressure is required to push water through smallest pores. Since the pores are so small (nano sized) bigger particles can clog the pores and this effect known as “fouling effect” is one of the main challenges in membrane based water filtration technology. Fouling makes the membranes unusable.

Conventional membrane materials include mesoporous ceramic membranes (2-50 nm pore size, useful for ultra filtration, common ceramic materials include sintered and ordered arrangements of alumina, silica, zirconia, mullite ($Al_2O_3.SiO_2$)), oxide mixtures, sintered metals, organic membranes (for both microfiltration (50-500 nm) and ultra filtration (5-50 nm)) and thin film composite membranes. Mesoporous ceramic membranes have high thermal, mechanical and chemical stability. Membrane lifetime is also high, but they are too expensive and limited to small scale applications. Organic membranes are porous polymeric membranes. Cellulose acetate was the one of the first membranes employed as polymeric membranes. This has been developed as RO membranes and is considered as the “last globally big invention in water purification” (this happened in 1959). Development of thin film composite membranes was another breakthrough in the membrane technology. In these composite membranes, an ultrathin monomer is polymerized over a macroporous polymer. Ultrathin polymer membranes can be one of the materials like polyamide, polyurea etc. Polyamide membranes are the only membranes used in big RO plants and are the only ones effective even in a single shot of water passage.

Major developments in water technologies could be possible due to recent advances in materials science, nanotechnology and the fundamental understanding of the solid-water interface. Over the past decade nanotechnology has rapidly changed from an academic pursuit to commercial reality. Apart from the concept of pore



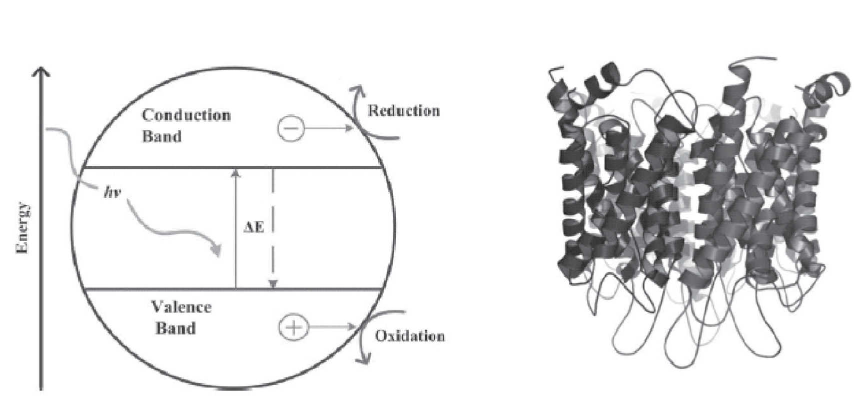
Various membranes and types of contaminants removed



(a) Development of Reverse Osmosis (RO) over the years. The dotted lines indicate the minimum energy required for RO, since it is a reversible thermodynamic process. (b) Schematic of reverse osmosis.

size based contaminant separation, the ion-exchange membrane (molecular sieves) concepts, developed with nanotechnology, could help to remove the heavy metal ions selectively from water. Nanostructured ceramic membranes were developed and they seem to be highly efficient in ion separation. Zeolites based nano-ceramic technology was another big leap in the membrane development. Zeolites are naturally occurring aluminosilicates and Si:Al ratio is the important factor determining the properties of zeolites. Engineering the Si:Al can change the ion selectivity, hydrophilic properties and chemical stability. The development of reactive/catalytic ceramic membranes was another water purification technique emerged with the development of nanomaterials. Reactive surfaces containing semiconductor nanoparticles such as titania/ZnO/ferric oxide are applied for water treatment. The membranes are activated by UV or sunlight to introduce photocatalytic process for the degradation of organic compounds. Since, in the case of nanoparticles, when a photoelectron is generated both electrons and holes are available for interaction with its environment due to the very high surface area and reduced size, they can oxidize or reduce the contaminants effectively. Application of photocatalytic reduction in water treatment was introduced in 1976.

A major issue in this technique is the recovery of nanoparticles. A clever approach to this issue is made by the usage of magnetic iron oxide or iron oxide coated catalyst, which would enable magnetic recovery of nanoparticles. Moreover, low field magnetic separation is one of the cost effective ways to remove the contaminants. Advancement in nanotechnology also leads to the development of hybrid membranes or mixed membranes. Low porous membrane will adversely affect the high flow rate of water, which is an essential requirement for pilot plants. We want to keep the higher water flow rate of macroporous membranes with increased retention capacity of nanoporous membranes. Use of nanomaterials with conventional membranes will help to solve this issue. Nanomaterials such as carbon nanotubes can remove many hazardous materials and dangerous compounds from water. Combining these nanomaterials with conventional materials such as sands were proven to be efficient in removing various types of contaminants in a high water flow rate. Aligned carbon nanotubes (pore size ~1-2 nm) can completely desalinate sea water. Synthesis of such highly stable membrane



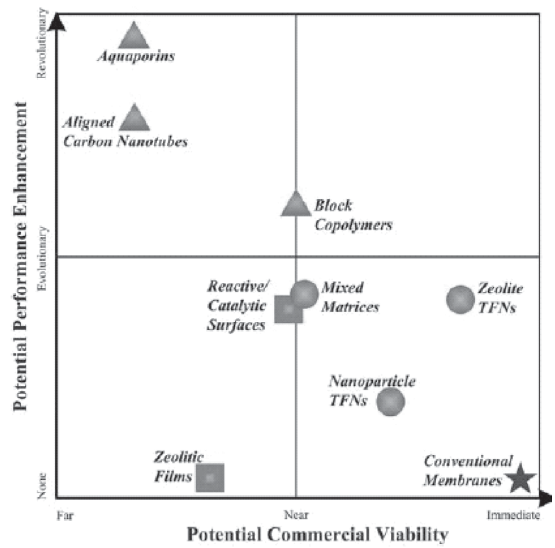
(Left) Schematic of excitons generation in a semiconductor nanoparticles, (Right) biologically inspired membranes (aquaporin).

is a technological challenge and will meet success in the near future. Moreover, aligned nanopores can create a potential over their surface and this will also help to repel oppositely charged ions in water. Development of various types of membrane architectures also help to make the water treatment cost effective. Previous closed membrane morphologies are no longer there and open geometries of membranes are available. This will help to backwash membranes to remove the contaminants.

All the contaminant particles need to be removed before leading the water to RO membranes to avoid the fouling effect (since RO membranes are highly expensive) and nano filters and knowledge of surface engineering and chemistry are essential to address these issues. Nanofiltration requires less energy compared to RO. Nanomaterials having high surface exposure can interact with water efficiently. A hybrid stacking or cascade arrangement of all types of membrane technique in a higher flow rate will help to make the water fresh in a single passage. Recently there are some new promising nanomaterials such as graphene oxide membranes, for the water treatment with unimpeded permeation of water through them. But current technology needs improvements to achieve this goal.

Discovery of biologically inspired membranes is an advancement in this field. Aquaporin membranes seem to be highly efficient in removing the ions. Aquaporins are the protein channels that control water flux across biological membranes. Aquaporins are found in human tissues with the purpose of rapid transport of water across cell membranes. Water movement in aquaporins is mediated by selective, rapid diffusion caused by osmotic gradients. The highly selective water permeability of aquaporin channels is an interesting concept for water treatment. Biological lipid bilayers contain aquaporins transport water and maintain selectivity that far surpasses all commercial RO membranes. The chart summarises the scenario of present membrane materials and their potential availability.

The innovations in nanotechnology and other advances in materials science can make it possible to transform our vision of plentiful fresh water at a low cost to a reality. Cheaper materials, more efficient equipments, and some promising new approaches could make large-scale extraction of clean water and nanotechnology a major force in the battle against global thirst. We need to implement new water policies in our society. The old centralized water purification concepts should be changed to region wise systems. Moreover, public awareness on the world water issues will also help to face the challenges. ■



Potential performance and commercial availability of various membrane materials

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Completing 50 Years of Excellence - Department of Physics
Cochin University of Science and Technology

Having been in existence for half a century and made significant contributions to physics, the Department of Physics, Cochin University of Science and Technology, is celebrating its Golden Jubilee in 2013. The Department has given eminent leaders to such newly started departments like Electronics, Instrumentation and Photonics, each of which has carved out its own niche of development. Whatever achievement the Department has earned is the result of the dedicated and sustained efforts of its faculty members, students, and non-teaching staff, under the generous and continued support of Central and State Agencies.

A brief history:

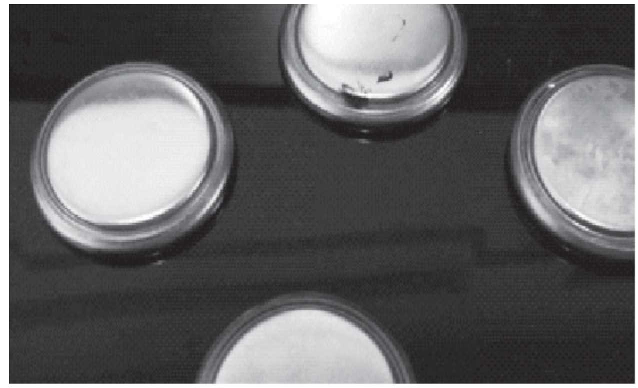
Established as one of the five Departments of the erstwhile Ernakulam Centre of University of Kerala in 1963, the Department of Physics became an integral unit of University of Cochin, founded in 1971 and renamed as Cochin University of Science and Technology in 1986. The famous molecular physicist, Prof. K. Venkateswarlu, a grand-student of the Nobel Laureate Dr. C.V. Raman, was the founder of this Department. He started the PG programme and the premier research centre for Physics in Kerala. Under his leadership and guidance the Department made several important contributions to areas like molecular dynamics and infrared and Raman spectroscopy. His colleague Prof. Joy George started research in solid state physics by setting up laboratories for crystal growth and thin films. Prof. M.G. Krishna Pillai and Prof. C.P. Menon also played key roles in expanding the research potential of the Department in molecular physics and solid state physics. It was under Prof. K. Sathianandan's dynamic leadership that a new era was opened in experimental physics in the Department. He developed a strong research group that excelled in areas like laser spectroscopy and laser technology. Prof. K. Babu Joseph initiated research in various areas of theoretical physics.

The creditable services of faculty members such as Prof. K.G. Nair, Prof. G. Aruldhas and Prof. V. Unnikrishnan Nair, contributed to the growth at early stages of the Department. Prof. K.P. Rajappan Nair, Prof. Elizabeth Mathai, Shri. P.K. Sarangadharan and Shri.M.M.Kuttappan contributed to the strengthening of teaching and research in experimental solid state physics and spectroscopy. Prof. C.P. Girijavallabhan, Prof. Jacob Philip, Prof. V.P.N. Nampoori, Prof. V.M. Nanadakumaran and Prof. P. Radhakrishnan, who later migrated to various other departments in the University, deserve grateful appreciation for their part in the intense research and development activity led by Prof. Sathianandan. The roles played by Prof. V.C. Kuriakose and Prof. M. Sabir in embellishing the department's research record in theoretical physics are remarkable.

The department owns to itself the singular credit of gifting two of its alumni as Vice-Chancellors of CUSAT: Dr. K. Babu Joseph and Dr. Ramachandran Thekkedath and Prof Godfrey Louis as the Pro-Vice Chancellor.

Polymer LED

The department is proud of its alumni, including thousands of M.Sc and hundreds of M.Phils and Ph. Ds. According to the department's records, one hundred and eighty seven students, trained by the department, have been awarded the Ph.D. Degree in Physics.



Li ion coin cell

The department admits annually 25 students for M.Sc course and 8 students for M.Phil programme.

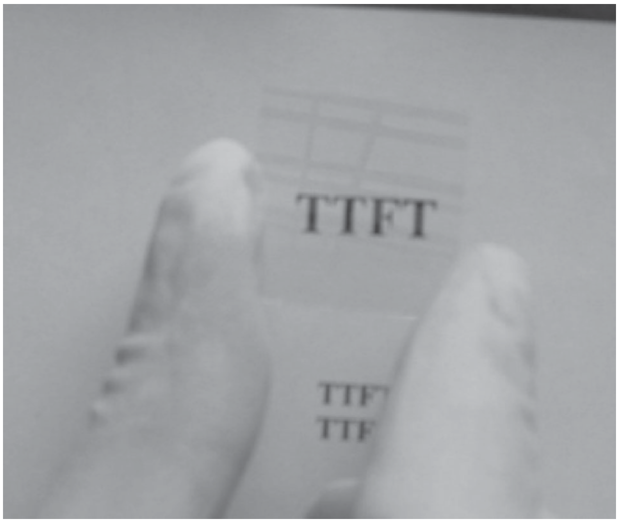
Research Activities

The department now have about eight research divisions and four centres spanning its research activities in applied optics, magnetic materials, advanced materials for batteries, polymers, solar cells, nanomaterials, optoelectronic devices, astronomy, atomic and quantum optics, particle physics, quantum computation and information.

The development of photopolymer films which could be used for holographic recording is taken up as an interdisciplinary programme including faculties from Department of Physics, Department of Applied Chemistry, and Department of Polymer Science & Rubber Technology. The LEDs based on polymers and small organic molecules, Li ion cells which are flexible and environmentally friendly, polymer based super capacitors and semiconductor quantum dots for nanophotonic and biophotonic applications are the research activities supported by Indian space organisation and defence research laboratory. Graphene and graphene oxide, are being synthesised by adopting chemical routes and further research on these materials to realize graphene-only high performance light emitting diodes and photovoltaic devices are underway.

Considerable amount of work has also been carried out on the surface structure determination of spinel like ferrites using low energy scattering techniques. One notable achievement is in the elucidation of surface structure of normal spinels in the nano regime.Investigations on Magneto calorific effect (MCE) of various ferrites and synthesis of alloys for MCE applications are also underway

Nanophotonics and optoelectronics research area include transparent electronics, solar cells, nanophosphors, quantum wells and quantum dots, ferroelectric random access memories, spintronics, non-linear optical studies, laser induced and RF plasma studies, surface enhanced Raman scattering studies and biophotonics. Low coast spray technique for the fabrication



Transparent thin film transistor

of II-III-VI2 based solar cells have been optimised. This technique is now being automated and fabrication of large area devices are in progress.

A theoretical physics research group has been active in the Department for about 40 years. The theory division, taking its birth in the early seventies under the leadership of Prof. K. Babu Joseph, is one of the active groups in the Department. While the early interests of the group centred around classical mechanics, foundations of quantum mechanics and conventional field theory, later its interests broadened, particularly after the addition of several new members. The group has been actively engaged in the study of particle physics, high temperature superconductivity, super fluidity, nonlinear dynamics, neural network phenomena and biophysics. Now this division has extended its research activities to areas such as quantum computation, atomic physics, quantum optics, Bose-Einstein condensation CUSAT is now one of the participating Indian Institutions under the MOU with Fermilab (USA) and the theory group with other faculty members in the Physics Department is planning to get involved with various neutrino experiments at Fermilab.

Extension Activities and Collaborations

Since 2006 onwards Department in association with IUCAA Recourse Centre, SPIE and ECS is organizing a 10 days summer programme for school children. One of the main activities of the programme is to give training in small telescope making. From 2009 onwards IRC also engaged in visiting schools. In this visit programmes, talks on elementary ideas of astronomy was given followed by giving training in making small telescopes and the programme ends with sky watching. When astronomical events like, solar eclipse, lunar eclipse, transit of Venus took place, arrangements were made by departmnent to view such events using a 6" telescope. The department conducts an open house programme every year and public and school children are encouraged to visit and see the activities of the department.

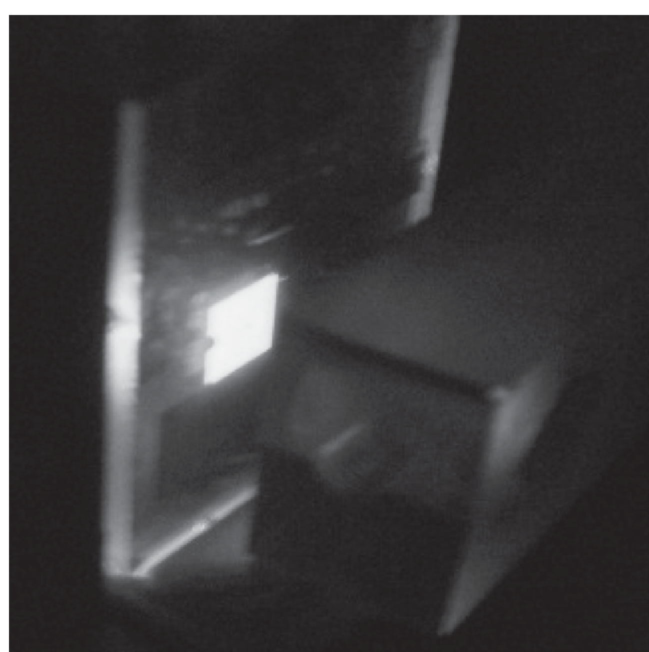
The Department was identified as an Associate Centre under Theoretical Physics Seminar Circuit of DST. Inter-University Centre for Astronomy and Astrophysics, Pune established IUCAA Resource Centre (IRC) in the Department in 1999 to promote research and teaching in astronomy and astrophysics in the University and in neighbouring institutions. ■

For more details about the department and for golden jubilee celebration please visit web:

http://physics.cusat.ac.in/

Contact. phys@cusat.ac.in
Phone. 0484-2577404

Courtesy :
Golden Jubilee Brochure.



Electroluminescent display

Physics beyond the Planck Limit

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Introduction

The Standard model of particle physics successfully explains three of the four fundamental forces and the particles associated with these forces. Many predictions made by this theory will be verified by the Large Hadron Collider in the near future. However, this theory cannot be regarded as a complete description of nature as it ignores gravity. The main problem is that the quantum effects of gravity become relevant only at high energies and very tiny distances. This limit beyond which we need a quantum theory of gravity is known as the Planck Limit and the regime that exists beyond it is called the Planck regime. This happens when the energy is of the order of 10^{19} GeV, distance is of the order of 10^{-35}m and time scale is about 10^{-43}s. Such numbers are typical of the Universe just after it came into existence. These numbers, excluding time are relevant to black holes also. Beyond Planck limit, the Standard model breaks down. The case with General Relativity is similar. The predictions of General relativity are correct only upto this limit. In the Planck regime quantum effects of gravity has to be considered. But combining General Relativity that explains gravity and quantum mechanics has proved to be impossibly difficult. In the Planck regime, all known & tested laws of physics breaks down. So, it would appear as if there is no physics in the Planck regime. But, over the last 3 decades advances in theoretical physics point to the fact that this may not be the case. The theories that predict phenomena that occur in the Planck regime are so strange that, if one or more if them are proved correct, it might change the notions of space and time for ever. This article examines three contenders to the position of a theory that quantizes gravity consistently and predicts the existence of a sensible Universe. This theory could be called a Theory of Everything as it combines gravity and quantum mechanics. It could also explain, among other things, what happens at the central depths of a Black Hole, where a unification of gravity and quantum mechanics becomes necessary.

What causes the breakdown?

Beyond the Planck limit, the basic problem is with the nature of spacetime itself. *Quantum fluctuations*, which can be ignored when far away from this limit, play a central role in the Planck regime. The predictions of almost all theories suppose a smooth structure of spacetime. It is this notion that breaks down at very small distances. Spacetime becomes a roiling, chaotic and messy entity, wherein the geometrical notion of direction and time lose significance. This appears to be a problem with our current theoretical model of spacetime. In fact, we don't have a correct theoretical model that takes quantum mechanics and relativity to such tiny distances. Mere rescaling of our knowledge to such small scales does not seem to work. This creates the problem described above. It is a solution to this problem that the to-be-discussed theories try to provide.

String Theory (Superstring theory)

This is the relatively older of the theories to be discussed. It was invented by Gabriele Veneziano in the late 1960sto explain interactions among hadrons. It was seen that the many properties of particles could be explained by the Euler's Beta function if they were characterized as one dimensional objects. But soon it was found that this theory could handle gravity also. Here, fundamental entities of matter and interaction are not point like particles but one dimensional entities called strings. A string can be open, with a particle at one end and an antiparticle at the other, or it can be closed. The different particles have different masses because they are composed of strings that vibrate with different resonant frequencies. It is the various resonant patterns of strings that give rise to differences in mass, charge etc. In a way, this unifies the constituents of all matter. The constituent is the string, which is same for all particles. The resonant frequencies differ, which differentiates the various particles. It creates interest particularly because, one type of resonant vibration corresponds to a zero mass particle with spin 2. This precisely is the graviton, the messenger of gravitational force. So, String theory naturally includes gravity in its framework. The mass of particles and the energy of vibration of the string are also connected. More massive particles have strings having larger energy that vibrates more frantically.

The 'Super' in String Theory

Another significance of String theory is that it includes a concept that has been developed in point particle quantum field theory – Supersymmetry. To see the significance of this concept, supersymmetry has to be discussed in some detail. It is a theory based on symmetries of spacetime and other subtle aspects of invariance. This theory predicts a 'supersymmetric partner' for all known particles in this Universe. For every fermion (half integral spin particles) there is a bosonic superpartner. For every boson(integral spin particle) there is a fermionic superpartner. It literally doubled the number of elementary particles. This might seem extravagant, but it comes as a solution to many problems. First, bosons and fermions have opposing quantum fluctuations that can cancel themselves out. This solves the perilous problem of quantum fluctuations to a good extent, because the problem of quantum fluctuations becomes relevant only at Planck energies, and it is conceivable that at such high energies, we might find the superpartners of all known particles. They are not detected at low energies because of their high mass (i.e. mc^2 mass). With the fluctuations cancelled out, the spacetime fabric could be a much calmer place. So, Supersymmetric Standard Model, the Standard model of particle physics with supersymmetry included, is more successful than its predecessor. The second advantage comes from the idea of Grand Unification. It is known that as the distance between interacting particles decrease, the electromagnetic force gains magnitude. But for the strong and weak forces, it decreased as distance was decreased. It was seen that at sufficiently high energies, the behaviour of all the forces would be the same. A diagram depicting the possibility is shown in fig. 1.

The coincidence shown is perfect...almost. It was seen that without the inclusion of supersymmetry, the unification of the forces was not perfect – i.e. the 3 forces did not converge to the same point. But with supersymmetry included, this convergence was perfect. So, it is assumed that supersymmetry should be a concept having some truth in it.

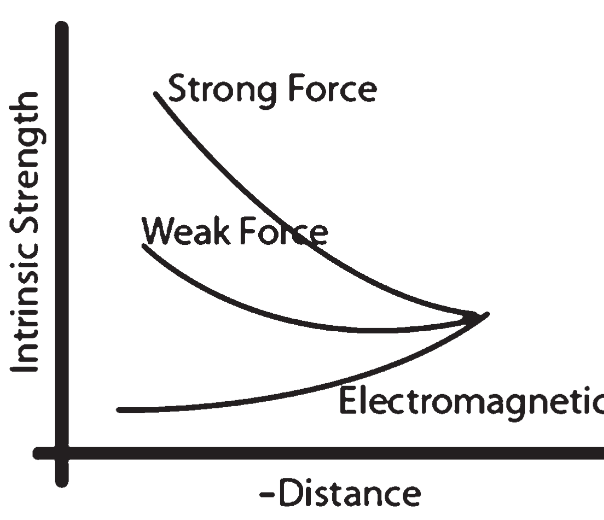


Figure 1. Variation of intrinsic strength of forces with decreasing distance

When string theory was first formulated, it included only bosons and was called bosonic string theory. But this theory had a problem – one type of resonant vibration corresponded to Tachyons. Whenever tachyons appear in a theory, it is a tell tale sign that there is something wrong. But future work in this direction led to the inclusion of fermionic vibration patterns. A peculiar feature was that it was found that the fermionic and bosonic vibration patterns of strings came in pairs – a sign of the inclusion of supersymmetry. Thus was born Superstring theory. It was found that the numbing problem of tachyons does not appear in this theory. But it was found that supersymmetry could be included in 5 different ways, and all the five versions of the superstring theories were equally correct. The five versions were Type I theory, Type IIA theory, Type IIB theory, Heterotic type O(32) theory and Heterotic type $E_8 \times E_8$ theory. All were equally correct. But, there can be only one truth and only one T.O.E, not five. This problem was initially a challenge to reckon with. But in the 1990s, it was proved by Edward Witten that the 5 different theories are like mirror images of one single theory, viewed from 5 different perspectives.

More Dimensions than you will ever need...

The next aspect of string theory is equally strange. It requires more spatial dimensions than 3. In fact, for string theory to be correct, it *requires* not just 3 or 4 but a total of 10 spatial dimensions. So Universe, according to string theory is eleven dimensional (10 +1 time). The question arises, where are the rest of the dimensions? As far as the theory is concerned, they are all 'curled up' so that they cannot be detected by us. The idea of curled up dimensions goes back to the 1920s when TheodorKaluza and Oscar Klein proposed a 5 dimensional spacetime to unify gravity and electromagnetism.The idea did not catch on then, but became relevant once unification of forces became serious. Many such Kaluza Klein theories exist. As for string theory, it requires 10 spatial dimensions because otherwise, some calculations lead to negative probabilities. When the cause was sought, it became clear that if the strings could vibrate in more independent directions (which implies higher dimensions), this problem could be resolved. An important result that comes from this consideration is that fundamental properties of particles like mass, charge etc in usual spacetime is determined by the size and shape of these extra curled up dimensions. So it becomes exceedingly important to understand the structure of these curled up dimensions.

What do these Dimensions look like?

It became clear that the understanding of the structure and geometrical properties of the extra dimensions is necessary to know how particle properties are generated. After much searching, a class of six-dimensional shapes seemed to fit the requirements. These are called 'Calabi – Yau' spaces. The problem is that there are many such spaces. Knowing which one to fit in is a challenge. Initially, String theory required 9 spatial dimensions instead of 10. It is with the formulation of Superstring theory that the total spatial dimensions became 10. The theory that united all the 5 string theories, and which talks about a 11 dimensional Universe is called the M – theory. In here, in addition to one dimensional strings, one can have 2 dimensional membranes as fundamental constituents. They

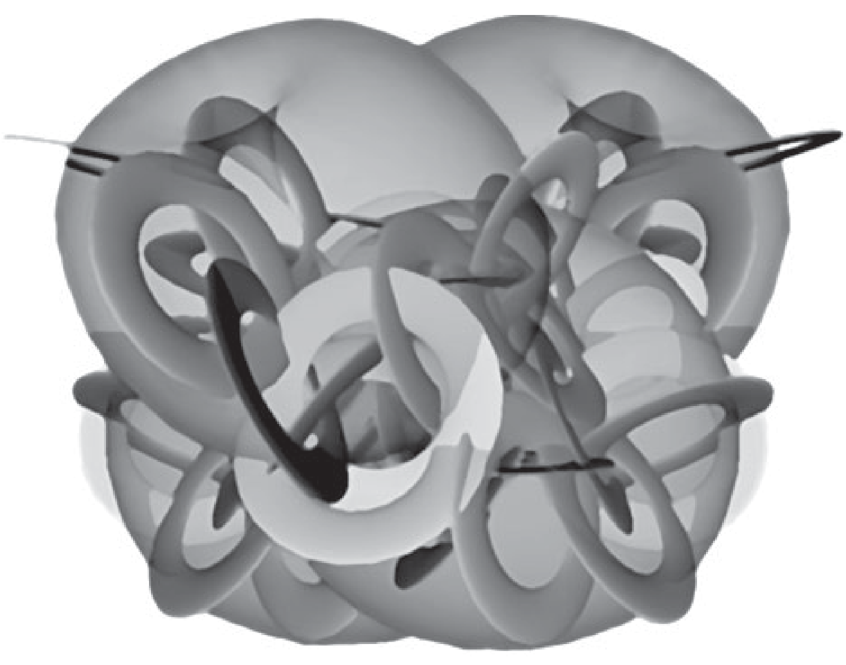


Figure 2 Calabi Yau manifold

are called 'branes' for short. Even higher dimensional branes have been proposed. A picture of the Calabi – Yau' manifold is shown in fig2. This should not be mistaken to be the full picture, as the space itself is 6 dimensional. The picture is a 2 dimensional projection on to the paper surface. So, this is what the curled up dimensions look like.

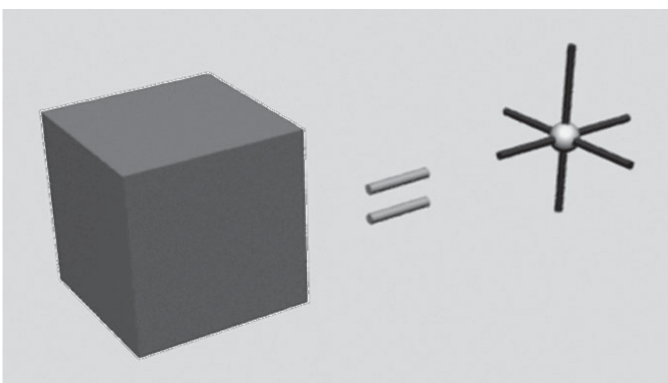
The Solutions...

So, with all these conceptual &mathematical jargon, can early Universe and black holes be explained? The fact is, not conclusively. Rather than providing an answer directly, following its own inner logic, string theory has unearthed its own set of complexities. For one thing, the mathematics of this theory is so complex that, today we have only approximate equations of string theory. Separating one Calabi Yau space from a huge collection of them, which will describes our Universe is still under way. As for black holes, the same condition above applies. Only for extremal black holes does string theory have a solution. These are black holes that are very specialized in their mass, topology, charges etc. Rather than giving a straight forward answer as to what happens inside a black hole, String theory can explain how black holes can be formed in its own language. But this should not lead one to think that there is a failure. In fact, at least for the aforementioned black holes, the theory offers an explanation for the microscopic origin of black hole entropy. Not just that, according to string theory, black holes and elementary particles are connected in strange ways. A black hole can shrink itself and form a resonant vibration similar to a graviton. The exact mechanism is clear in theory, but it is quite a long shot. Plus String theory deals with a variety of singularities other than the black hole singularity. As for the quantum mechanics – general relativity merger, the answer is even more stranger. Calculations show that unlike particles, whose capability to probe smaller and smaller distances increase with increasing particle energy (due to smaller De Broglie wavelength), the string does something different. Initially, its behaviour is just like the point particle's one. But further increasing energy to extreme limits increases its size rather that its distance probing capability. This happens at around the planck energy. This means that, the fundamental constituent of matter, the string, is insensitive to sub-planck length scales. It is not capable of probing the sub-Planck length scale. Any endeavour in this direction will result in the string getting larger. So String theory does away with the wild quantum fluctuation problem and the infinities that come along. At first sight, this might seem as if string theory actually evades the problem rather than solving it. But, the proponents of this theory claim the infinities to be a problem inherent in the point particle framework itself. In the String theory framework, this problem does not arise at all. Gravity is inherent in this theory and quantization of strings does not lead to infinities. So, as far as the proponents are concerned, String theory IS the Theory of Everything. As for the origin of the Universe, the M - theory speculates many tantalizing possibilities. Explaining these would over-strain the constraints of space. It suffices to say that, if String theory is true, the Universe is far more stranger than it meets the eye. Possibilities include a Holographic Universe, wherein, the Universe is thought to behave like a hologram – generating 3 dimensions even though the hologram itself is 2 dimensional.

Loop Quantum Gravity (LQG)

Today, LQG is the strongest contender to String theory. As it is evident from the above explanations, String theory needs 7 extra spatial dimensions to be consistent, none of which are observable. Plus, it is assumed that M Theory will be the superset which will include string theory as a subset. But, the details of this theory are still unclear. A need for an alternative was clear by the 1980s. Previous attempts of quantizing spacetime described by Einstein's theory failed because of a loophole – the assumption of the continuity of spacetime at all scales. The proponents of LQG tried to quantize spacetime without this assumption. They kept 2 assumptions of General Relativity intact – first one, known as background independence, says that the geometry of spacetime is not static but evolves in time. To find the geometry, equations that include the effects of matter and energy has to be solved. The second one, known by the name diffeomorphism invariance, basically implies that one is free to choose co-ordinates to express equations of spacetime. Incidentally, String theory is not background independent; the equations assume the existence of a spacetime.

The calculations revealed a new possibility – space and time could be quantized. The ‘quantum’ of space is about 10^{-35}m is size. Similarly, the smallest tick of time possible is about 10^{-43}s long. So, a quantum of volume is about $10^{-99}cm^3$ in size and a quantum of area is about $10^{-66}cm^2$ in size. All these dimensions are in the Planck regime. So in these scales, the spacetime loses its



continuity and becomes granular. But the Universe is not simple as a large number of tiny spheres existing at tiny distance scales. The geometry of spacetime is described by a more complex mathematical structure known as *Spin Networks*. The mathematical structure is too complex to be elaborated here, but what is done basically is the following. A cube is represented by 6 lines representing 6 faces & a central dot, called a node, representing volume. Numbers are given to nodes and lines, representing volume of the object and area each face represent.

Each quantum stateof the area or volumecan be represented by such a graph. It is a network of such graphs that represent space itself. Space is made up of such quantum volumes and it is these quantum volumes that add up to the space around us. Since each of these volume is represented by a graph like the one shown above, a large network of such graphs represent space. It is called *Spin Networks*, spin representing a property of these graphs. How each of these graphs can be connected to build space as a whole is dictated by the mathematical formalism. The particles in the Universe, are represented by certain nodes. In the diagrams, they are represented by giving additional labels to already existing nodes. Fields on the other hand are represented by giving additional labels to the ‘lines’ in the graph. The changes in space, in accordance with the background independence are represented by changing the connectivity of graphs. When we include time, these nodes change to lines. The lines change to surfaces. The spin networks are now referred to as *Spin Foam*. Using quantum mechanical rules for calculating probability for the occurrence of events, probability for phenomena in the spin foam can also be found out.

The equations of LQG are given by difference equations rather than differential equations, which is a result of the assumption that spacetime becomes grainy at small distances. The solutions of these equations gave a strange result. At extremely high energy densities, gravity can become repulsive. The proponents like to compare spacetime as a sponge, and energy as water. The sponge has a limit upto which it can soak up water. After this limit, it does not soak up water. Rather, it does not permit any introduction of water inside. This is analogous to saying that it is repelling water. Similarly, there is a limit to the energy that granular space can contain. Beyond this limit, gravity is overwhelmed by a new force that comes into light due to quantum considerations of general relativity using LQG equations. This force is *repulsive*. This happens when space is of Planck dimensions.

An Infinite Universe with Cosmic Forgetfulness?

This concept of a repulsive force taking over gravity eliminates the possibility of the pernicious singularity that forms at the centre of a black hole or the singularity at the Big Bang. As energy density starts to become extremely high, due to extreme compression of space, this new quantum force comes into play. So, instead of a big crunch to a singularity, we have a big bounce, an explosive expansion of spacetime due to the large repulsive component. This can also explain the big bang. Instead of the big bang, it could have been a big bounce as explained above. But then, bounce from where? It could be from another Universe that was undergoing a crunch. Or it could be from a black hole. This means that this theory eliminates the notion of finite space or finite time. Space and time could be infinite, undergoing many bounces and proceeding forever.

A significant question that appears is, what about the past of such a bounced Universe? Will it have any ‘memories’ of the past? Early calculations by LQG theorists, including among others, Abhay Ashtekar of

Pennsylvania State University showed that in a completely symmetric Universe with only zero mass particles that do not interact, the Universe before and after the bounce would be remarkably similar. But recent considerations show that this might not be the case. The details of the Universe that existed before will be erased and the present Universe arises from a completely random configuration. So, the repulsive force is not a brief period of a really big push with the before and after scenarios remaining the same. In other words, the Universe after the bounce carries no memories of the past. The fluctuations in the Universe that results after the bounce will be different from those that existed before.

The theorists consider this as a blessing rather that a curse. A Universe with no memory of the past does not have the traces of its entropy either; otherwise the configurations will have some similarity. So if the Universe before the bang had some entropy, and if all of it was carried over to the 'new' Universe, it will not have enough energy to form galaxies and structures of the like. Without the past memories and traces, the Universe starts anew. But, there is nothing like a perfectly clean beginning. Theorists hope to find at least some of the clues left behind, that can give the idea of the Universe 'before'. Two candidates are neutrinos and gravitational waves, since these are not easily affected. The theory also proposes a long shot – different wavelength electromagnetic waves travelling at slightly different speeds due to the peculiarity in the quantum geometry of granular spacetime.

The strengths of this theory are that it gives away with the infinities and singularities plaguing classical relativity. Plus it includes cosmological inflation. The bounce that a Universe undergoes is nothing but an accelerated expansion of spacetime. The bounce, or expansion stops when the energy density is small enough for gravity to take over the repulsive force. This is precisely what inflation is.

As with String theory, the regime of atomic spacetime is Planckian. So a direct measurement may not be possible. But by studying the Microwave radiation background, the imprints left on it by the gravitational waves may provide a hint to the results predicted by LQG. As with any other emerging Quantum gravity theory, work is still in progress. Here, there are no extra dimensions or exotic phenomena. But it predicts equally strange phenomena at tiniest of distances – especially a repulsive force.

Causal Dynamic Triangulation (CDT)

This is the latest of the three theories we consider. If CDT proves to be true, more than anything else, it will prove String theory to be a true embarrassment of riches. The strongest advantage of this theory is that it gives away with multi dimensions and such wild concepts. It is a reminiscent of what is known as Euclidean Quantum Gravity, propounded by Stephen Hawking. It is based on General Relativity and one of the fundamental principles of Quantum Mechanics – superposition. The theory applies superposition principle to the Universe itself. Different possibilities of the evolution of the Universe in time are superposed to find a general shape and size of the spacetime continuum itself. With the advances in scientific computing, this technique received boosts and computer simulations could be made that represented curved spacetime. In those simulations, triangles were used to simulate a curved surface. This is because, triangular meshes can be used to approximate curvature. An example is elaborated below:

Fig. 3 shows a 'sphere' created out of just 8 triangles – 4 on top pyramid & 4 on bottom. Fig. 4 shows the same sphere with more triangles added. With the addition of more triangles, the sphere finally takes shape. The curved surfaces are created by adding a large number of triangular meshes with the adjacent meshes joined together.

It is easiest in computer simulations, to use triangles to simulate 3 dimensional objects. Actually, all 3D applications use this principle. When physics is brought into these simulations, we find that simulation of the general structure and shape of spacetime is possible. The significance of such structure and shape is that it is this structure of spacetime that gives rise to gravity, as expounded by Einstein in General Relativity. The microscopic origin of these structures obviously has to take Quantum Mechanics into account. The simulations take into account these facts. The triangles themselves have no physical significance, as the structure is obtained when the size of the triangles is reduced to zero. Then, it doesn't matter if we had triangles or polygons. Only the collective behaviour of these triangles are of significance. It can be compared to a flock of migratory birds that form a pattern in the sky, wherein the size shape etc of individual birds do not affect the shape of the flock as a whole.

However, there is one difference. The structure we are trying to simulate is 4 dimensional. So what we need are '4 dimensional generalisation of triangles' (triangles are 2 dimensional).These are technically known as 'simplices'. The structures we are trying to glue together turns out actually to be 3 dimensional tetrahedra, which are the faces of the so called four-simplices. In the usual case what gets glued are one dimensional objects – lines of 2 dimensional triangles. Just like gluing together triangles which are 2 dimensional objects, creates a higher dimensional object like a sphere, fixing together faces (which are 3 dimensional) of '4 dimensional triangles' called simplices creates a 4 dimensional structure of spacetime.

Fitting in causality

When such simulations were done in Euclidean Quantum Gravity, it was found that the simulations were lacking something. The quantum superpositions were inherently unstable. The quantum fluctuations of curvature on very short distance scales do not cancel themselves off. These fluctuations represent different superimposed Universes. So, the final result is either an infinite dimensional, crumpled up tiny Universe, or an infinitely thin and extremely extended Universe. Both of these Universes don't resemble ours.

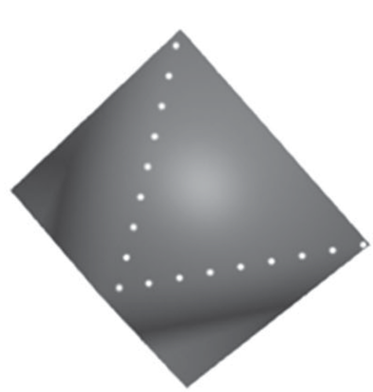


Figure 3. A 'sphere' approximated by minimum triangles.

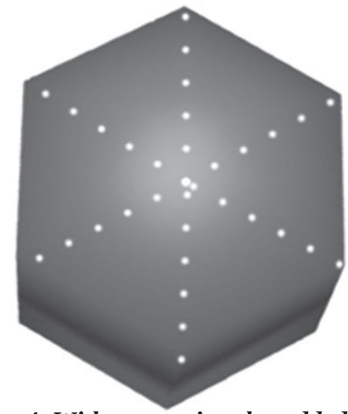


Figure 4. With more triangles added, the shape starts to reveal itself.

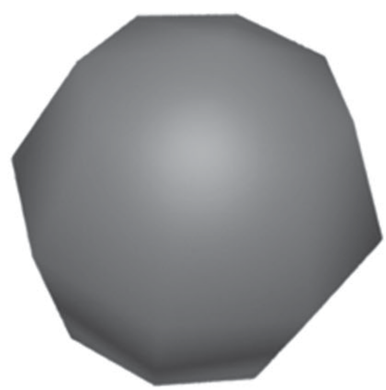


Figure 5. Sphere? Well...

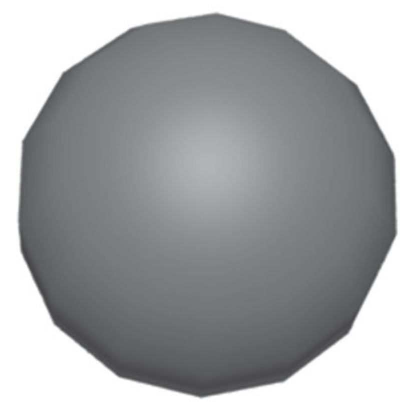


Figure 6. Almost...

Figure 7. A sphere approximated with triangular meshes

This was because in Euclidean Quantum Gravity, time is not properly taken into account. The simplices could evolve back or forth in time. In other words, *causality* was not taken into account. Rather, causality was expected to evolve as a consequence of the general structure of spacetime. So, in CDT, causality is assumed to be built into spacetime rather than expecting it to be a consequence. In their simulations, the proponents of CDT included the finite velocity of propogation of information, so that cause always preceded effect. Each simplice was encoded with a so called 'arrow of time' which pointed to the future only. This meant that when these simplices are joined together, the joining should be in such a way that both should have the arrow of time pointing in the same direction. When one simplice evolves forward in time, the adjacent one should also evolve forward, rather than going back in time. So, all simplices had the same sense of time. When this was done it was found that thestructures that emerged were different from those of Euclidean Quantum Gravity. In 2004, a simulation of the large scale structure of spacetime was conducted. The aim was to check the dimension of the spacetime that formed as a result. The answer, astonishingly, was four! This theory, without wild concepts or farfetched imaginations could create a spacetime that resembled our Universe.

Further simulations to test whether this theory agreed with the results of general relativity showed that it needed to include the Cosmological Constant for the model to work. Moreover, the structure of spacetime thus obtained obeyed DeSitter geometry, a known solution to Einstein's equations of general relativity. Thus the emergence of a 4 dimensional spacetime and the inclusion of cosmological constant, a number that is increasingly becoming significant are the central achievements of CDT.

A Fractal Universe?

The simulations were extended to study minute distance scales, a strange result emerged. The dimensions of space at such small distances depend upon the scale at which it is been probed. In other words, spacetime for an elementary particle may be vastly different from what it is for us. The results showed that the Universe, i.e spacetime attains a fractal property at very small distance scales. A fractal has the property that it is self similar. No matter what the scale, it looks the same. Examples are the Sierpinski Gasket or the Cantor Set in Mathematical Physics.The scale at which the Universe attains this property is near 10^{-35}m, known as the Planck length. In this limit, quantum fluctuations become significant that the DeSitter geometry that could explain the Universe so far fails. The usual notions of space, size etc also drops – all of which are true for a fractal. The dimension of the Universe at such small scales according to CDT is 2. But it continues to be continuous. A possibility predicted is that Universe becomes self similar below a threshold distance. So, no matter how small the distance is, it would look the same as any distance scale below the threshold. In that case, CDT will prove String theory and LQG wrong: no strings or spacetime atoms but just a self similar structure.

It should be mentioned that the concept of a dimension has different definitions: mathematicians have a Hausdorff Dimension, wherein the exponential power to which distance is raised (for eg: in 3 dimensions, V á r^3) gives the number of dimensions. Spectral Dimension describes dimension in yet another way. For CDT, the spectral dimension is of significance. Simulations for understanding behaviour of spacetime at large and other properties in presence of matter are under way. Only after that will this theory be able to answer the questions regarding black holes or early Universe. If this theory turns out to be true, it will be the simplest one to describe spacetime.

Conclusion

As seen from our above discussions, it is evident that, once freed from the confines of experimental verifications, theories can run amok. Many of the theories predict the existence of parallel universes – existing already or those which can spring forth from black holes. It should not be mistaken that just because String theory has been elaborated much, it is holding the biggest chance to be true. What remains to be seen is what nature has chosen as the truth. In the future, we may have one of the theories as a winner. Only then will we have a Quantum Theory of Gravity. Until then gravity remains elusive. There is a wilder possibility: what if more than one of the above theories were proved right. There are some who consider String Theory and LQG to have some connections. If that happens, then neither of them will be true. We will have to have yet a new theory that includes both the theories as special cases. Theoretical physicists will never find themselves jobless. Just like the theories above requiring almost insane energy levels to be tested for verification, theoretical physicists will almost be permanently safe. ■

APT - Talent Search Examination 2012
- A Report

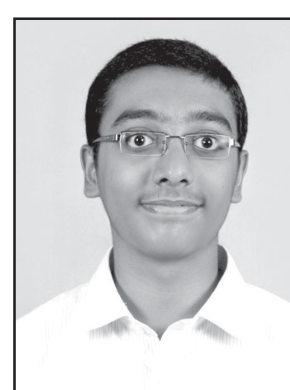
Dr. Manju T.
S.S. College, Kalady

The Academy of Physics Teachers, Kerala has conducted the year 2012 edition of the Talent Search Examination (APT – TSE 2012) on 22nd September. It was a huge success with participation from 53 colleges all over Kerala. Out of nearly 1500 students registered for the examination, 1171 students appeared for the exam that was held at 46 centres across Kerala. The written exam consisted of two parts; Part A with 75 objective type questions and Part B with descriptive type questions. Out of the candidates, 127students who scored 60% and above qualified for the evaluation of their Part B answers. 30 students who secured the top marks in Part A and Part B together, were called for an interview on 15.12.2012 which was held at the Department of Physics, CUSAT. The interview board included Dr. M. K. Jayaraj, Prof. P. J. Kurien, Dr. Jayaprakash and Prof. K. Y. Shaju. All the students fared well in the interview and the final rank list was prepared based on their written exam score together with interview marks. **Ms. Ann Mary Mathew** of Assumption College, Changanassery is the topper in TSE 2012. **Jobin Sebastian** of St. Joseph's College, Devagiri won the second position and **Mithun K. P** of Govt. College, Madappally and **Athul C. Arun** of Bharata Mata College, Thrikkakara shared the third position. A complete list of the toppers and their score is given below:

Ann Mary Mathew
Assumption College,
Changanassery

Jobin Sebastian
St. Josephs College,
Devagiri

Mithun. K. P.
Govt. College, Madappally



Athul C Arun
Bharata Mata College,
Thrikkakara

Rank	Name of the student	Name of the College
1	Ann Mary Mathew	Assumption College, Changanassery
2	Jobin Sebastian	St. Josephs College, Devagiri
3	Mithun. K. P.	Govt. College, Madappally
4	Athul C Arun	Bharata Mata College, Thrikkakara
5	Chinthak Murali	W.M.O. College, Muttil, Wayanad
6	Fairoos C .	Govt. College, Madappally
7	Kshama Sara Kurian	Providence College, Kozhikode
8	Aparna Sankar	Govt. A Sc. College, Kozhikode
9	Anjana Ashok	Govt. A Sc. College, Kozhikode
10	Sachin Sukumar P.	M.G. College, Iritty
11	Haripriya V. K.	Vimala College, Thrissur
12	Adwaith K. V.	Govt. A Sc. College, Kozhikode
13	Dayal G.	Catholicate College, Pathanamthitta
14	Kannan V. M.	St Thomas College, Thrissur
15	Sreenidhi K. S.	M.E.S. Ponnani College, Ponnani
16	Wilfred Thomas	St. Thomas College, Thrissur
17	Muhsina R.	Christian College, Chengannur
18	Sajith V. S.	St. Thomas College, Thrissur
19	Shamna A.	Farook College, Kozhikode
20	Silpa B.S.	Govt College, Madappally
21	Nipun Chandran V. M.	M.G. College, Iritty
22	Aathira Murali	Christ College, Irinjalakuda
23	Sreenath K. G.	Christ College, Irinjalakuda
24	Anooja J.	S.N. College, Kollam
25	Deepthi S. Prabhu	K.K.T.M. Govt. College, Pullut
26	Polly Rose	MG College, Iritty
27	Reshmi O.	St. Joseph's College, Devagiri
28	Jyothis G. S.	S.N. College, Kollam

The organizers express heartiest gratitude to the regional coordinators for their enthusiastic support towards the successful conduct of TSE-2012. The list of regional coordinators is given below.

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India-based Neutrino Observatory -
Some frequently asked questions

Prepared by: **The INO Team**
TIFR, Mumbai

- The India-based Neutrino Observatory (INO) is an effort aimed at building a world-class underground laboratory to study fundamental issues in science. It is a mega-science project under the XII five-year plan of Government of India with an investment of about 1350 crores, jointly funded by the Department of Atomic Energy (DAE) and the Department of Science and Technology (DST).
- The ambitious INO proposal has already drawn the worldwide attention of both national and international scientists. Once completed it will be the largest basic sciences project in India.
- At present, nearly 26 institutions and about 100 scientists are involved in the INO collaboration with Tata Institute of Fundamental Research, Mumbai, being the host institution. This large collaboration is the first of its kind in the country and is expected to grow further.
- The laboratory is to be located in Tamil Nadu as the steep slopes of the western ghats provide ideal and stable rock conditions for building a large underground cavern,
- The primary goal of the laboratory is the study of neutrinos from various natural and laboratory sources using an iron calorimeter (ICAL) detector. It is envisaged that such an underground facility will develop into a centre for other studies as well, in physics, biology, geology, etc., all of which will make use of the special conditions that exist deep underground.
- The ICAL detector that will be installed in the INO laboratory will be the world's most massive detector. Such an effort will involve INO-Industry interface in a big way, in issues related to mechanical structure, electronics and detector-related technology. It is being developed completely indigenously.

Apart from pursuing neutrino physics goals, the laboratory itself will greatly aid the development of detector technology and its varied applications (which have so far been in the areas of medical imaging).

- Students of science and technology within the country, particularly those residing in Tamil Nadu or neighbouring states, will have the opportunity to involve themselves in research involving cutting-edge science and technology.
- INO has no strategic or defence applications. Its operation involves no radioactivity release or toxic emissions.

General Information

Over the last few years many questions have been asked about the proposed underground laboratory, INO. Below we list some of these questions and our response:

What is INO?

The India-based Neutrino Observatory (INO) is a proposed pure-Science underground laboratory. Its primary goal is to study the properties and interactions of weakly interacting, naturally occurring particles, called *neutrinos*. The objectives of the study are appended in simple layman's language at the end of this FAQ. There is world-wide interest in this field due to its implications for several diverse and allied fields such as particle physics, cosmology and the origin of the Universe, energy production mechanisms in the Sun and other stars, etc.

In fact, other neutrino labs, also underground, have been running for several years in places such as Japan, Italy, and Canada. The experiments proposed at INO will be complementary in nature to the existing ones. While many experiments have studied neutrinos from the Sun and other stars, INO will study atmospheric neutrinos that are naturally produced by the interaction of cosmic rays in Earth's own atmosphere.

Several groups belonging to different Universities, IITs and research Institutes in India are part of the collaboration working on the research & development of all components of INO. This is an open collaboration and interested people are welcome to join. The current proposal focusses on neutrino detection with static detectors, to be placed deep underground at a suitable site. A short account of the physics goals and implications is appended at the end of this FAQ.

Where can one find detailed information about INO?

Many articles, talks and reports about INO are available from the following websites:

www.ino.tifr.res.in/

www.imsc.res.in/<"ino

The websites provides the current status and is continuously updated. We appreciate inputs from our scientific colleagues. It also contains information for students and non-technical material accessible to the general public.

What are the highlights of the proposal?

The INO proposal consists of creating two underground laboratory caverns with a rock cover of more than 1000 metres all around to house detectors and control equipments. An access tunnel of length 2 km (approximate) to reach the underground laboratory will be driven under a mountain to reach the laboratory caverns. The surface facilities near the portal will consist of a laboratory and some housing for the scientists, engineers and operating staff. There will be no other tunnels and hence no disturbance on top or the sides of the mountain; the only entrance to the underground cavern will be at the bottom of the mountain.

What will be the detector that will be housed at INO?

The detector housed in the INO laboratory initially will be a magnetised iron calorimeter detector (ICAL). It is a static device without moving parts. Just as a telescope observes the sky through visible light, the ICAL will observe the sky through neutrinos.

Charged particles produced in the rare interactions of neutrinos with the iron (constituting the 50 kton, 1.3 Tesla magnet) will be detected in glass based detectors called RPCs sandwiched between successive iron layers. The penetrating ones, such as muons, will be tracked in space and time to identify their charge (+/") and momentum. In addition to ICAL, several small experiments may also be housed in INO.

What will be the detector that will be housed at INO?

The main detector housed in the INO laboratory will be a completely indigenously developed magnetised iron calorimeter detector (ICAL). It is a static device without moving parts. Just as a telescope observes the sky through visible light, the ICAL will observe the sky through neutrinos.

About 150 layers of active glass-based detectors called RPCs will be sandwiched between layers of iron (constituting the 50 kton, 1.3 Tesla magnet). Charged particles such as muons produced in the rare interactions of neutrinos with the iron will be detected by the RPCs. These will be tracked in space and time to identify their momentum and charge (+/-). The properties of the neutrinos will be inferred from these tracks.

In addition to ICAL, several other small experiments may also be housed in INO.

Will there be any radioactivity?

No. The main reason for locating the laboratory underground is to create an environment free of the radiation that abounds on the Earth's surface. This radiation is due to cosmic rays and natural radiation of the materials around us. Hence the experiment will neither produce any radioactivity nor can it function well where there is radiation (at the Earth's surface).

Will there be hazardous chemicals and gases?

The RPC detectors measuring the impact of charged particles produced in neutrino interactions with the iron consist of glass sheets kept at a precise separation and hermetically sealed to maintain the purity of a certain kind of gas mixture at about atmospheric pressure. The gas mixture used in the experiment consists of mainly argon, freon (environmentally friendly variety that is now used in all modern refrigerators), small quantities of isobutane and trace amounts of sulphur hexafluoride. These are used regularly in all laboratory environments and the mixture that will be used will conform to international standards of safety. The gas mixture is recycled many times before it is let out in small volumes. The ventilation system mixes the released gases with air to ensure the safety of every one. This is more a precaution to ensure the safety of the workers inside the laboratory.

What is the status of the proposal?

The INO proposal has been approved as a mega project for funding during the XII Five Year Plan of the Government of India.Pre-project works are going on at present

What are the time frames for the project from time zero?

The present road map envisages that the first module of the detector will start taking data at the end of five years. Immediately after that the subsequent modules will be constructed. The first year of the project will be devoted to exploration, finalisation of designs, identifying the contractors etc. The next two years will involve excavation of the tunnel and laboratory cavern. During the last two years the laboratory equipment and detector construction will begin.

What were the factors in deciding the location of the project?

Since the laboratory cavern needs to be more than 1000 m underground (so that there is at least 1000 m cover all-round to absorb/reduce natural cosmic radiation), the choice of site is primarily dictated by the rock quality, in order to obtain a stable safe environment for such long-term activity. Geologically, southern Indian mountains have the most compact, dense rock (mostly gneiss) while the Himalayas are mostly metamorphic sedimentary rock with pockets of gneiss. A considerable area of peninsular India, the Indian Shield, consists of Archean gneisses and schists which are the oldest rocks found in India. While the Karnataka region has more schistic type rocks, the rock found in BWH is mainly Charnockite, which is the hardest rock known. The mountains of Tamil Nadu, in general, are the most attractive possibility, offering stable dense rocks with maximum safety for locating such a laboratory. Apart from this, availability of water and power and easy access to the site for maximum work efficiency are other factors.

How many people are to be located at the site?

During the construction phase there will be a work force numbering about 100 or so. During the heavy construction phase the personnel needed includes civil engineers, drilling crews, truck drivers and concrete workers. There will also be design, architectural, and engineering crews along with geologists. The finishing work will require electricians, ventilation engineers, and environmental engineers. As described in our proposal, we estimate that the project will employ several permanent staff members and visiting scientists drawn from several laboratories. Only a small fraction of these will spend a substantial part of their time at the underground laboratory. About 20-30 scientists and engineers will stay permanently at the location for operational reasons apart from a floating population of students and scientists.

What will be the environmental impact of INO?

The impact will be mainly during construction period; after construction ends within a few years, the lab will be maintained by a small staff with some students and scientists and will have negligible environmental impact. All efforts will be made to minimise and manage the impact during construction.

2-12. Does INO have an environmental policy?

Yes. The challenge for INO is to build a world-class science laboratory, keeping in mind the ecological and environmental concerns, especially during the construction phase, and to actively participate in on-going conservation efforts in the region.

- During its normal operation phase, the laboratory is not expected to cause any damage to the environment. All efforts will be made to minimise the disturbance during the construction phase.

- INO will ensure that its activities are in conformity with environmental laws as are applicable.
- All members of the collaboration, executing agencies and their workers will be trained to cooperate in ensuring compliance with environmental guidelines.

It is imperative to recognise that the study of Nature's innermost workings need not be at loggerheads with Nature itself. Models of S & T development that are sensitive to environmental conservation thus assume importance. The proposed India-based Neutrino Observatory (INO) offers immense opportunities and a challenge for realising such a model.

Where is the project located?

The proposed site for INO is located in the Bodi West Hills region, about 2 km from the nearest village Pudukottai in Pottipuram Panchayat, Theni District of Tamil Nadu. The nearest major city is Madurai about 110 km away. It is also the nearest airport and a major railway station.

The portal is proposed to be located outside the RF boundary in puramboke (revenue) land along with surface facilities. This land, about 26.85 Ha in area, has now been aquired for INO. The Cavern will be located about 1300 metres deep under the 1589 peak (see Fig.2).

The proposed site for INO is located in the Bodi West Hills region, about 2 km from the nearest village Pottipuram, Theni District of Tamil Nadu. The nearest major city is Madurai about 110 km away. It is also the nearest airport and a major railway station. The portal (entrance to tunnel), the lab complex and the surface will be in Theni district.

While the laboratory and surface facilities are open to the public with prior permission, admission to the area will be regulated based on safety and operational considerations.

Where is water for the project coming from?

Water will be piped in from outside. The Tamil Nadu Water and Drainage Board (TWAD) has been approached to provide a suitable water source which will not affect the present usage in local villages.

How will you manage electricity when there are severe power cuts?

The power consumption, when the laboratory is fully functional, is about 3MW which will be sourced from the Sub-station in Rasingapuram directly. Further, when there is a power cut, diesel generators will be used to the capacity required.

Possibility of using wind generator is being explored.

How will you ensure that noise from blasting does not disturb the environment or people?

Controlled blasting will be adopted in the intitial reaches to dampen noise and vibrations. Blasting noise lasts only a fraction of a second and is not a continuous disturbance.

Blasting to be carried out for excavation of the cavern and associated components underground is likely to cause low vibrations. However, it is likely to be much lower because of the overburden of hard rocks and soils, except in the case of the initial sections of the tunnels. Nevertheless, INO will undertake ground vibration monitoring study during actual execution of the project along with other rock mechanics and instrumentation studies as done in similar underground project already commissioned nearby. The ground vibration may be measured continuously during blasting operations for all the major components of the project. Appropriate blasting pattern and modern blasting techniques based on the actual site geology, may be adopted such that vibration due to the blasting is the minimum.

Estimated particle velocities are shown in Fig.3. For example, at 500 m from the portal it is approximately 3.4 mm/s and on the peak above cavern (about 2000 m from portal) it is approximately 0.5 mm/s.

INO laboratory is situated deep under ground, about 1300 m below the hill peak. The tunnels and caverns will be excavated through controlled blasting in the initial reaches.Initial stages of blasting will be two pulls in daylight hours only. When both noise and vibration levels subside, deeper underground, there will be three pulls of blasting per day.

During the operation phase, there will be a workshop and a detector assembly facility to assist day-to-day maintenance. It will not have any noise-generating heavy machinery. In the utility building located next to the portal, modern chillers and blowers, with reduced noise levels, will be used. Silent DG sets will be installed within the utility building. Indigenous trees will be planted around the utility building for further damping of noise during operation phase.

How much muck will be generated?

The first few tens meters or so (till stable rock face is reached) of the tunnel will be executed through cut and cover method. The top soil removed during this stage will be stored separately and reused for backfilling/greening the dump yard. Most of the muck to be disposed of will consist of rubble stones/ boulders debris, which has great use in road re-laying and construction activities. The tentative estimate for the total tunnel debris generated during excavation of underground components, including allowance for about 18% voids, is approximately 224,000 cubic meters as shown in the Table. As the tunnel is in stable hard rock, the dust generated will be minimal (less than 10% of the total rock muck).

The processed rock debris generated during excavation is used effectively to replace (about 80% of) the sand required for construction of both underground and surface facilities.

This quantum will be generated over a 3 year period. About 20% of this will be consumed for INO works; for tunnel and cavern floor, for concrete lining and shot creting of tunnels/caverns, levelling and in construction of buildings and facilities.

Efforts will be made to evacuate muck as it is generated, minimising storage at the site.

Where will you store this muck? Also, it is very windy 6 months of the year. How will you protect adjoining areas?

The muck store yard will be protected by dry stone masonry wall, all around except for entry and exit points, to prevent contamination of any nearby water sources. This will also reduce wind effect. A protective wind fence using either metal sheets (as is done in urban areas) or fabric will be placed around the muck storage yard above the wall to prevent spread of particulate matter.

How will you arrange for there to be no dust on roads?

The standard solution is water-spraying and covering the transport vehicles.

Generators

Silent generators will be used. Appropriate trees will be planted around the utility building to further reduce noise.”>If you are using generators, how will you reduce noise and air pollution? Silent generators will be used. Appropriate trees will be planted around the utility building to further reduce noise.

Silent generators will be used. Appropriate trees will be planted around the utility building to further reduce noise.

How will you handle so many lorries for transport? If you are having a lot of truck movement on the access road, will you make sure that the road is suitably built and maintained?

All material transportation will be done using the direct road from the site to the state highway near Rasingapuram completely avoiding the transportation through the villages (see Fig.5). The number of vehicles used for transportation will be regulated based on the existing traffic pattern on these roads.

There are three components to the issue of transportation: Firstly, the mud road leading to the portal (with bridge crossing the stream) will be upgraded to a two lane road (about 1900 metres long).

Secondly, the existing metalled road, up to the outskirts of Rasingapuram will be widened using its present width itself.

Thirdly, a by-pass road to the extent of about 0.5 to 1km will be constructed to avoid going through Rasingapuram. Most of this will lie in the revenue puramboke land. No restriction on the use of the road constructed for the project will be imposed. We are requesting the state government to help us in this construction and maintenance. ■