SIGMA

THE JOURNAL OF THE MATHEMATICAL & ASTRONOMICAL SOCIETIES

UNIVERSITY OF CEYLON, COLOMBO. 1969 — 1971.

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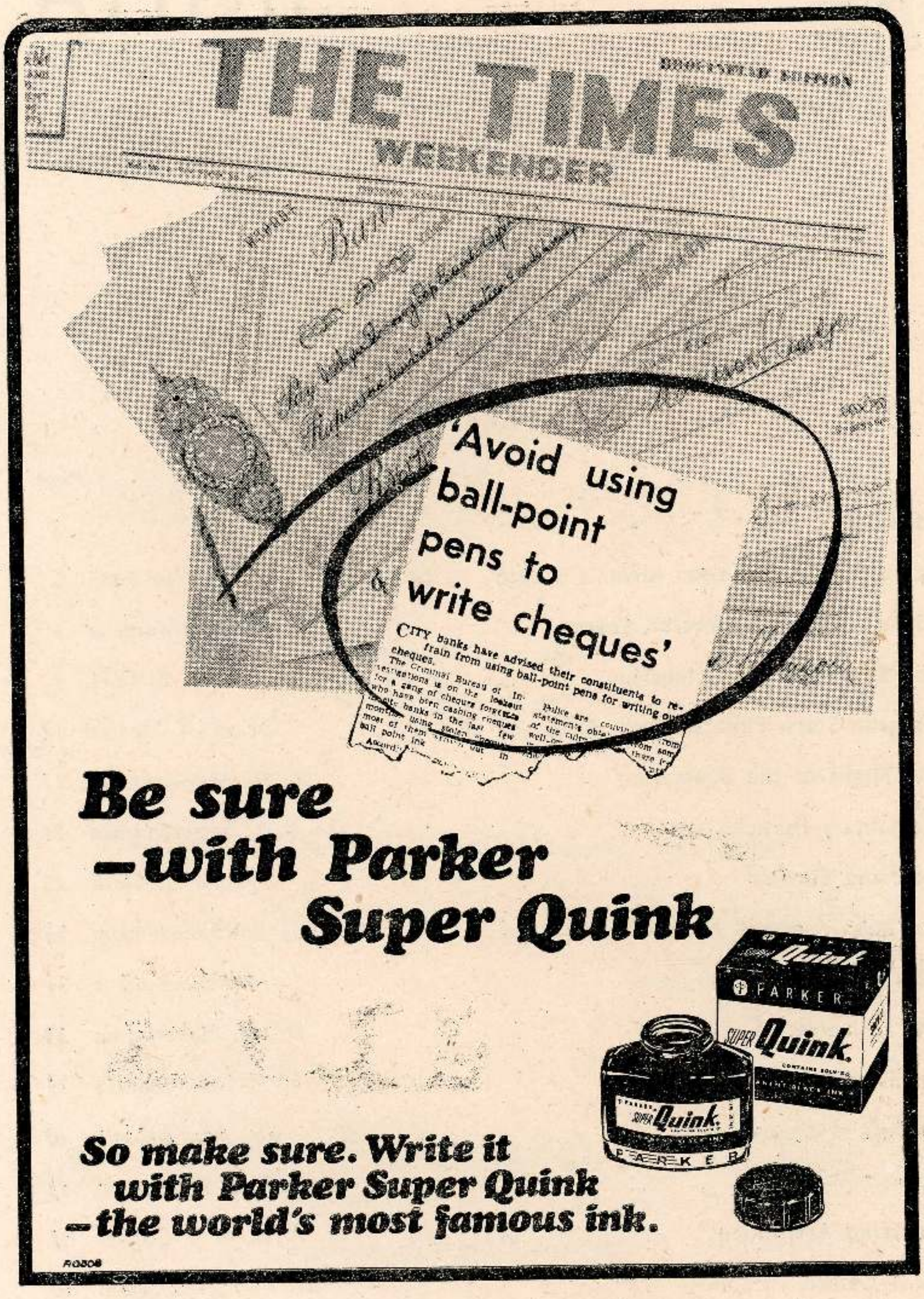
THE TIMES
WEEKENDER
'Avoid using ball-point pens to write cheques'
CITY banks have advised their constituents to refrain from using ball-point pens for writing out cheques.
Be sure
—with Parker
Super Quink
So make sure. Write it
with Parker Super Quink
—the world's most famous ink.
PARKER
SUPER Quink
Quink

Editorial

On "Useless" Knowledge

THERE are three ways of pursuing knowledge. One way is to pursue it for some thing which is lower than knowledge: for a career or for the power which knowledge gives. A second way is to pursue knowledge for its own sake. This has been the goal of scientists and most of those who have genuinely sought knowledge. Yet another way is to seek knowledge for some goal which is higher than knowledge: for an outlook an attitude or a world - view which remains after the details of what we have learnt are forgotten — in short, for what is usually called wisdom.

The greatest scientists and thinkers who have illuminated our minds and have contributed to a large extent towards what we call civilization belong to the last two categories. We regret to note, however, that these two categories of knowledge have now come to be characterised, particularly in our own country, as "Useless" Knowledge.

According to this last view, a mathematician battling with the rigours of analysis or an astronomer gazing through his telescope, is pursuing "Useless Knowledge". He is wasting his time on "Socially irrelevent research" which a developing country like Ceylon can ill afford. Useful knowledge, according to this view is not knowledge which has a bearing on our values or which helps to develop a broad and humane outlook in life. It is knowledge, which brings material benefits, an ingredient in technical skill or which in some way contributes to the physical and material advancement of man.

This view in effect subscribes to the extreme materialist philosophy as expressed in the words of Feurbach: "man is what he eats." This is the antithesis of the other extreme view, that man is what he thinks. We believe however that man is both flesh and mind: Too much emphasis on one of these aspects cannot lead to a happy life, even though it may be satisfying at certain times. Thus while granting that applied research is important and essential we cannot agree that pure research is useless.

Apart from this, the narrowly utilitarian conception of konwledge cannot even achieve its own ends. Some of the technical devices which are widely in use today have been the outcome of pure research. Appiled science, without a proper basis in Pure-science cannot proceed very far. Neglect of pure science and pure research in general, would, in the long run, prove harmful to our country.

Extracts From The Speech Given on 26. 3. 71

AT THE UNIVERSITY OF CEYLON, COLOMBO

by

PROF. HANNES ALFVEN

(Nobel Laureate, 1970; Prof. of Physics University of California; Prof. of Physics Royal Institute of Technology, Stockholm; President, Pugwash Movement; Member, National Academy of Sciences U. S. A. and U. S. S. R.)

(Compiled by M. Thillai Nadesan)

"THE spirit of science is to fight ignorance and fight superstitions; ...... ignorance and superstition is the background of the nationalistic feelings and many of the dangers which threaten the world......"

"......Today the theme of my lecture will rather be, looking at our planet as something which belong to all of us-namely space research. I think one of the most impressive (outcomes) of the research are, photographs from the space crafts. You will see the earth as something like the moon and also you will realise it obviously that our planet is the only known place where we have any life and we have to make the best possible use of this planet. We must see that we do not disturb the planet by warfare...... Population is increasing at the present rate it is an essential responsibility for all Scientists to see how this state of affairs, the present trend, can be changed and **must** be changed soon, and changed in a **drastic** way......"

......"It is an international enterprise...... But one has often the impression that these two super powers (U.S.A. and U.S.S.R) are competing. This is true to a certain extent. But it is equally true that there is so much collaboration which perhaps has not received so much publicity. But there are so many scientists travelling between the two countries, discussing the results of space research in the U. S. and in the U. S. S. R. And there are other nations joining in now........."

"......the bringing back of samples from the moon. The results of these have been a great surprise to the scientist. There have been many guesses about the composition of the moon, I am not actually referring to the old thesis that the moon actually consists of **green cheese!** and since people may have thought about the chemical composition and structure of the moon, there are so many hypothesis, so many theories that one can almost say that almost of them are wrong. And this means that we must not speculate too much about space around and the only way......... is to go up there and see what it is like. Science is as it has always been, must always be, **empirical;** that theories or speculations about the universe around us are nothing compared to real facts which we get from the measurements and from bringing samples back, which we can analyse. The possibility to observe the defects of the structure of the moon from the earth using a telescope is very much restricted. You cannot study the light, moon or other planets emit, with it but if you can bring back small samples even if it is grammes you can learn so much from that........."

★ ★ ★

Some Thoughts on Vector Spaces

A. C. SIRIWARDENA

SETS of the form $V_n (R) = [(x_1,\ldots,x_n)/x_i$ belongs to R] belong to the type of algebraic systems known as vector spaces. If F is a field, a non-empty set V together with two operations + and . (i.e. addition and scalar multiplication) such that

$$\begin{cases} + : V \times V \text{ to } V \\ \cdot : F \times V \text{ to } V \end{cases}$$

is said to form a vector space over F provided certain well known conditions regarding the operations . and + are satisfied. The above definition is an abstract formalisation of the physical and geometric notions about vectors; the vectors in this case are the elements of V, and the elements of F are known as scalars. The vector space V_a (R) represents the n-d-imensional Euclidean vector space.

Let us consider the set

$$V = V_1 (R) \cup V_2 (R) \cup \ldots\ldots \cup V_n (R) \cup \ldots\ldots$$

i.e. the union of all the Euclidean vector spaces of various dimensions. Let us define two operations + and · such that

$$+ : V \times V \text{ to } V$$
$$\cdot : R \times V \text{ to } V$$

The sum of two elements of V shall be found according to the following rule:

$$(a_1,\ldots,a_m) + (b_1,\ldots b_n)$$
$$=(a_1+b_1,\ldots a_n+b_n, a_{n+1},\ldots, a_m)$$

When m is greater than n or m=n.

$$=(a_1 + b_1,\ldots,a_m+b_m, b_{m+1}',\ldots,b_n)$$

When m is less than n.

i.e. when adding two ordered n-tuples containing different numbers of coordinates we first add the corresponding coordinates till all the coordinates of one ordered n-tuple are exhausted. Then we merely write the remaining coordinates of the remaining ordered n-tuple as they are e.g.

$$(1,2,3,4,) + (2,3,5)$$
$$=(1+2, 2+3, 3+5, 4) = (3,5,8,4)$$

The product of a real number and an element of V will be found by the following rule.

$$a. (x_1,\ldots, x_m) = (ax_1,\ldots, ax_m)$$

The following properties are satisfied by the two operations.

1. $\mathbf{X}+\mathbf{Y} = \mathbf{Y}+\mathbf{X}$ for every **X** and **Y** belonging to V
2. $(\mathbf{X}+\mathbf{Y})+\mathbf{Z} = \mathbf{X}+(\mathbf{Y}+\mathbf{Z})$ for every **X**, **Y** and **Z** belonging to V.
3. There exists an element **O** belonging to V such that $\mathbf{X}+\mathbf{O}=\mathbf{X}$ for every **X** belonging to V. In this case **O** is the element (o).
4. $1. \mathbf{X}=\mathbf{X}$ for every **X** belonging to V.
5. $(a+b). \mathbf{X} = a\mathbf{X}+b\mathbf{X}$ for every a and b belonging to F and for every **X** belonging to V.
6. $a (\mathbf{X}+\mathbf{Y}) = a\mathbf{X}+a\mathbf{Y}$ for every a belonging to F and for every **X** and **Y** belonging to V.
7. $(ab). \mathbf{X}=a. (b\mathbf{X})$ for every a and b belonging to F and for every belonging to V.

Let us consider - systems of the above type (which we shall call X-systems for convenience) i.e. systems which consist of a set V together with two operations + and . such that

$$+ : V\times V \text{ to } V$$

· : FxV to V where F is a field with + and · satisfying the conditions 1 to 7 given above. We can see that the definition of a X-system is the same as that of a vector space with one difference; namely that in a X-system every leement does not necessarily have an additive inverse. For instance in the example considered, ordered n-tuples with more than one coordinate cannot have additive inverses. This is clear because any element added to such an ordered n-tuple will always give an ordered n-tuple with two or more coordinates and we can never make the sum equal to (O). Thus we have shown that there exist X-systems which are not vector spaces. In other words we have shown that in the definition of a vector space the additive inverse condition is not a consequence of the others; that is, it is independent of the others.

There is an interesting fact about X-systems concerning it's zero elements. In an X-system, as in a vector space, the zero element for the whole set i. e. the element **O** s, t. $\mathbf{X}+\mathbf{O}=\mathbf{X}$ for every **X** in V, is unique. This can be proved for X-systems in the same way that it is proved for vector-spaces since the proof is not dependent on the existence of additive inverses. However in a X-system, unlike in a vector space, individual elements of the set V can have several different zero elements corresponding to them. For instance, in the example considered, the element (1,2,3,4) has (o), (o,o),(o,o,o) and (o,o,o,o) as it's zero elements. We can easily show that this is impossible in a vector space. For suppose, an element **X** of a vector space has two zero elements **O** and $\mathbf{O}_1$ corresponding to it.

$$
\begin{aligned}
\text{i. e.} \qquad & \mathbf{X}+\mathbf{O} = \mathbf{X} \\
& \mathbf{X}+\mathbf{O}_1 = \mathbf{X} \\
\text{Therefore} \qquad & \mathbf{X}+\mathbf{O} = \mathbf{X}+\mathbf{O}_1 \\
\text{Therefore} \qquad & \mathbf{X}+(-\mathbf{X})+\mathbf{O} = \mathbf{X}+(-\mathbf{X})+\mathbf{O}_1 \\
\text{Therefore} \qquad & \mathbf{O} = \mathbf{O}_1
\end{aligned}
$$

This shows that each element of a vector space has only one zero element corresponding to it (and naturally, that is equal to the zero for the whole space.)

We can also prove another interesting result, namely that an X-system which has a unique zero corresponding to each element is a vector space. The proof is as follows. Let **X** belong to V.

$$
\begin{aligned}
\text{Then,} \qquad \mathbf{X}+(-1).\mathbf{X} &= 1.\mathbf{X}+(-1).\mathbf{X} \\
&= (1+(-1)).\mathbf{X} \\
&= \mathbf{O}.\mathbf{X}
\end{aligned}
$$

where 1 is the multiplicative identity of the field.

Now $O.\mathbf{X} = (O+O).\mathbf{X} = O.\mathbf{X} + O.\mathbf{X}$ Since $O.\mathbf{X}$ is a zero element corresponding to the element $O.\mathbf{X}$ it follows that $O.\mathbf{X}=\mathbf{O}$, the zero element for the whole space (which is also the unique zero for every element).

Therefore, $\mathbf{X}+(-1)\mathbf{X}=\mathbf{O}$ which implies that **X** has an additive inverse for every **X** belonging to V.

To sum up, we have reached two important conclusions.

1. In the definition of a vector space, the additive inverse condition is independent of the others.
2. Given all the conditions of the definition of a vector space, with the exception of the additive inverse condition, the above mentioned condition is equivalent to saying that every element of the space has a unique zero element corresponding to it.

It is interesting to speculate whether one can develop a theory of X-systems on lines similar to that of vector spaces. Since a vector space is a X-system it follows that whatever theory we create must reduce to the already existing one of vector spaces in the case when the X-system is a vector space. We will need new definitions of the concepts of linear independence, bases and dimensions which must satisfy the condition just stated. The inevitable question arises: even if we could create such a theory would it be purposeful to do so? It is true that this appears somewhat unlikely. We can establish a relationship between the theory of polynomials and the definition of X-systems by re-defining polynomials in a more or less unnatural way, especially as regards equality; however, to do so would not be of any conceivable use. What we require is some situation which falls 'naturally' into the new system. At first glance at least, one feels sceptical that such a situation could exist. However it is not entirely impossible that we are not looking in the correct places. For it may be worthwhile to remember that abstract mathematics often turns up applications, in areas which, when one looks at it superficially, do not appear to have much connection with it.

THE STRUCTURE OF THE NUCLEUS

Dr. B. G. LOWE

ONE hundred years ago the question "What is the structure of the atom?" might have been met with the derisive response, "the atom is the smallest possible unit of matter, how can it have 'structure'?" The inherent picture was that of a hard 'billiard - ball' with no features, which could not be subdivided. This picture served its purpose very well at that time, of course, and it was left to people like Bohr and Rutherford to show that it was in fact inadequate. The question then became a sensible one but a whole new mechanics (quantum mechanics) had to be developed before it could be answered. Physicists today feel that although the atomic problem is in many cases highly complex, it is understood, at least in principle. In other words, we understand the 'spirit' in which the atom operates.

The atom consists of a positively charged nucleus with negatively charged electrons in orbit about it. The electron-nucleus and electron-electron interactions are well understood and the rest follows in principle from modern quantum theory. This must however be relativistic (Dirac theory) in order to explain spin angular momentum, a part of the angular momentum which is intrinsic to the particle. Each electron moves essentially under the central influence of the nucleus as this is heavy and usually has the dominant charge. The residual (electron) interactions can then be added as a slight modification or 'perturbation' to the problem. Another perturbation which must be included is the so called spin-orbit term, which is a consequence of an interaction between the electrons' spin angular momentum and its orbital motion. The wave function of the electrons in the atom is antisymmetric, (electrons are said to be 'fermions') and as a consequence, the Exclusion Principle operates. That is, no two electrons in the atom can be in the same quantum state. Thus as the possible states are filled, the electrons fall naturally into energy groups or 'shells'. The whole basis of atomic structure and chemistry depends upon the sequence of levels in the shells and the operation of the Exclusion Principle.

This picture of the atom works very well and there are no violent disagreements with experiment. So we feel quite smug about this state of affairs. In recent years physics has been grappling with the question "what is the structure of the nucleus?" We are not nearly so happy about the answer to this one, but much progress has been made and we are beginning to get the feel of the problem.

Our picture of the nucleus is at first sight a confusing one as there appears to be a different picture for almost every one of its properties. It is a little like the problem of wave-particle duality. "Is light wave or particle?" The answer is "It depends what experiment you do!" Is the nucleus like a billiard ball, a toffee, a liquid drop or a gas? Do the neutrons and protons (called collectively 'nucleons') of which the nucleus is composed stick rigidly together, collide constantly with each other or move about fairly independently? Is it smooth, rough, diffuse or even spikey? The answer to all these questions as gleaned from various papers in the journals could be "yes!" What do we know? Nuclei are small, being only a few fermis in radius (one fermi is 10^{-13} cms). They are all of approximately the same density (about 10^{14} gms/cm^3) and roughly uniform throughout. The nucleons are held together by the nuclear force which must be considerably stronger than the electrostatic repulsion which exists between the protons. This latter effect however is responsible for the excess of neutrons over protons in heavy nuclei. Although the nuclear force is the strongest force known it is of very short range-one or two fermis-and does not obey the simple inverse squre law with which we are so familiar. In fact its true nature appears complex and is not yet completely understood.

The elementary particle physicist might insist "the two nucleon interaction is not understood, so how can you hope to understand the working of a nucleus which may involve hundreds of such interactions?" The mathematicians might even twist the knife and point out that the many — body problem is not solvable anyway! Well, this is true, but nuclear structure physicists are no more patient to await the details of the two body interaction and development of computational methods than chemists were to await the details of quantum orbital theory. The nuclear structure problem is interesting in itself and not unlikely to shed some light on the two body interaction anyway. The nuclear physicist is forced to construct pictures or 'models' of the nucleus and then to enquire experimentally into the validity of such models. This can lead to apparent confusion as already indicated. I shall mention here a few of the more important models of the nucleus which have been proposed.

Niels Bohr, the same great physicist who had simplified the picture of the atom and paved the way to the quantum description, constructed a highly successful model. This differed a great deal from his picture of the smooth workings of the atom in that the nucleons were considered to be interacting violently and continuously with each other in complete random motion. This model seems reasonable because it is known that nucleons do interact strongly and because they are confined to close quarters in the nucleus. High momentum nucleons are observed experimentally in the nucleus and this lends support to the idea of violent interactions. Moreover, low energy nucleous which enter the nucleus by bombardment are quickly absorbed and in the ensuing multiple collisions get "lost in the crowd." They then have nothing to distinguish them from any other nucleon in the nucleus. The energy merely goes to raise the nuclear 'temperature' and the decay to the ground state is completely independent of the mode of formation of this 'hot' nucleus. This picture of nuclear reactions works very well and has been extended to a similar model the Liquid Drop Model, by Age Bohr (Niels' son). After all, in a liquid drop molecules are moving rapidly (Brownian motion) and are confined to a small region of space. The analogy takes us through surface tension, deformation, vibrational modes, fission and even tidal waves around the nucleus! The model gives a good description of all these phenomena as they occur in the nucleus.

Another Model which has been highly successful in describing nuclear reactions is the so called Optical Model. When a high energy nucleon enters the nucleus it experiences the presence of all the other nucleons as an average force field or a potential 'well', Its velocity and direction are modified and this, of course is reminiscent of refractive index and the refraction of light in a glass ball. Hence the model has been called the 'Crystal Ball' or Optical Model. We also find that diffraction and total internal reflection can take place as well as some absorption i. e. a 'Cloudy Crystal Ball Model'. The absorption corresponds to the nucleon losing its identity as in the Bohr Models decribed above, and the extreme, where all nucleons which hit the nucleus are absorbed, is called the Black Nucleus Model. The diffraction patterns formed in a nuclear scattering experiment on this model are very like the haloes formed by the diffraction of light on lycopodium powder. The success of the Optical Model in describing nuclear scattering is of paramount importance as it shows that the interactions which must take place in the nucleus can in fact be averaged out as a smooth Optical Potential. This assumption is too often taken for granted, but it provides a powerful simplification.

The next step is to assume that not only does a high energy intruding nucleon experience such a potential, but that all the 'resident' nucleons in the nucleus also experience it. In other words, we can average out the effect of all the other nucleons as a smooth potential which is not now the Optical Potential but is the so called Shell Model Potential.

The Shell Model of the nucleus is perhaps the most successful and certainly the most popular of nuclear models. It has been shown to be a good approximation to the truth to a degree which could never have been anticipated. In it we picture each nucleon as moving about in a relatively unhindered and independent way; such a far cry from the Bohr picture that it is hard to imagine we are describing the same object! We are getting back to something approaching the atomic problem of a particle moving under the influence of a smooth potential-The Shell Model potential in the one case and the electrostatic potential in the other. In both we expect quantised energy levels which group to form shells. Do we observe a shell structure in the nucleus? The answer is yes. There is a vast amount of evidence. For example, the nuclei with proton or neutron numbers 2,8,20,28,50,82,126 are exceptionally stable, just as are atoms of helium, neon, argon etc. and for the same reason (closed shells). For many years physicists tried to find the shape of the potential which give these 'magic' numbers but with little success. Then Maria Mayer and Haxel, Jensen and Suess (1950) independently discovered that if a spin-orbit perturbation was added, just as in the atomic problem, the numbers could be predicted. The Shell Model proper was born. There is great intellectual satisfaction in these parallel descriptions of atom and nucleus. The Shell Model owes its validity to the fact that nucleons (like electrons) are fermions and the Exclusion Principle again operates. Thus many of the violent collisions predicted in the Bohr Model are inhibited, as these would lead to final states of the nucleons concerned which are already occupied. Experiments, while confirming the essence of this picture, also show it to be only an approximation, and residual interactions between nucleons and other perturbations, such as deformities of the potential well (Nilsson Model) have to be added in. This can be regarded as mixing in certain amounts of the Bohr Models so that we are really approaching the truth from the opposite extreme. The Shell Model in this form is remarkably good. Low energy experiments (bombarding energies up to 20 Mev say) which excite the nucleons into unfilled Shell Model levels and which watch the subsequent decays, verify our ideas. Recent high energy experiments (100 - 1000 Mev) in which nucleons are knocked out of the nucleus from the filled shells, deep in the potential well, also verify this general Shell structure. However, the theoretical description of these deep levels is not nearly so good.

We have then at least some remarks in answer to the question "what is the structure of the nucleus?" It is amusing now to compare the reaction of the physicists of over one hundred years ago to the atomic problem with our present response to questions like "What is the structure of the electron?"

Neutron Stars, Pulsars, Black Holes and all that

DR. D. A. MENDIS

NUCLEAR transmutation is the basis of stellar existence. By transmuting lighter nuclei into heavier ones via exothermic nuclear reactions deep within its hot interior a star continuously replenishes the enormous quantity of energy that it radiates from its surface into the cold depths of interstellar space. Unfortunately for any star its fuel content is finite. Consequently after a period, which is about 10^{10} years for the sun, and which is correspondingly smaller for more massive stars, all its nuclear fuel gets exhausted.

The behaviour of a star during its nuclear burning stage is orderly, unspectacular and pretty well understood at the present time. It need not concern us here. But what happens when a star has exhausted all its nuclear fuel? This question has intrigued astrophysicists for over half a century and although the first glimmerings of an answer were provided over thirty years ago, the entire picture has been brought into sharper focus only within the last seven or eight years. The present picture is characterised by extreme conditions and violent events.

The behaviour of a star, once its nuclear fuel is exhausted, is determined to a large extent by a single parameter - its mass. Rotation, magnetic fields, inhomogeneities, turbulence and composition, all no doubt play their parts. But the detailed role of each of these is rather imperfectly understood at the present time. The least massive stars die the most peaceful deaths. They gradually shrink to about the size of the earth and rest there as white dwarf stars - gradually dimming as they cool to almost zero temperature. Larger stars die more violently. They contract slowly at first but then begin to collapse catastrophically. A sudden release of energy may convert the implosion into a violent supernova explosion ripping the star apart and scattering the fragment into interstellar space. In some cases the star may collapse with increasing rapidity not stopping until it becomes an ultradense neutron star. Once again the outer regions may be blown off in the process. In yet other cases it may be impossible to arrest the collapse at any stage and the star may totally disappear from the rest of the universe into a so called "black - hole" in space.

White dwarf stars and supernova explosions have been observed and studied in detail by astronomers. Neutron stars are probably now being observed in the guise of Pulsars. As for black holes, there can be no direct observational support due to their very nature but some weak indirect evidence is already available in a few peculiar binaries. Besides the laws of gravity and the structure of matter. replace by, as they are understood today leads us inexorably to the conclusion that "black - holes" too must exist.

A large majority of the stars in the universe are less massive than 1.4 solar masses. Consider first the fate of such a star once it has consumed its nuclear fuel. It is the thermal pressure of the hot gas which constitutes the star that resists the inward pull of gravity (radiation pressure not being very significant at this stage). But as the dying star continues to radiate its remaining heat the thermal pressure weakens and gravity pulls it inwards. Gravitational compression reheats the interior and although half the heat generated flows outward to the star's surface and is then radiated away, the other half, which is trapped in the interior, pushes the temperature up. The increased radiation and gas pressure act to retard the gravitational contraction of the star.

Gravitational compression and heating does not continue indefinitely. When after several million years, the star has shrunk from hundreds of thousands of miles to several thousand miles in radius, its central temperature has climbed to nearly a billion degrees. The density of matter in the centre has risen from several pounds per cubic inch to several tons per cubic inch. Yet the resultant gas pressure and radiation pressure alone cannot stop the collapse, because the force of gravity within the star has also increased with the compression. What finally stops the collapse is the so called "degeneracy pressure" of the free electrons. According to the uncertainty principle no particle likes to be compressed. The smaller the particle's mass and smaller the volume into which it is compressed, the larger its resistance to further compression. In the star at compressions of a few tons per cubic inch the opposing degeneracy pressure produced by the free lightweight electrons becomes large enough to counterbalance forever the pull of gravity. The star achieves a stable configuration and is then called a white dwarf. Over a period of billions of years the white dwarf cools to a "black cinder" drifting endlessly in space. Such would be the eventual fate of our sun.

Like the lighter stars, ones more massive than 1.4 solar masses too are crushed by gravity once they exhaust their nuclear fuel. Unlike the lighter ones, however, they cannot counterbalance the pull of gravity even with the degeneracy pressure of the electrons. When the compression has reached white dwarf densities the force of gravity within the star is so large that it overwhelms the combined pressure of heat, light and electrons. With increasing contraction the advantage of gravity increases. Consequently the star collapses with ever increasing speed. During this collapse an enormous amount of heat is released in a very short time. So if the outer layers of the star are incompletely burned they would suddenly ignite and explode as a supernova - to shine for a few months as brightly as a billion normal stars. In other cases the nuclear explosion may be too weak to eject the outer layers and the entire star may continue to collapse with rising densities and temperatures until its core, falling fastest, becomes as dense as an atomic nucleus. During the core's collapse, which lasts only a few seconds the electrons are squeezed into the nuclei transmuting the protons into neutrons. These neutrons are finally packed side by side into one giant nucleus. At such close range they exert an enormous repulsion. If the collapsing star weighs less than about 2 solar masses the neutrons absolutely resist further compression and halts the collapse almost instantly.

The outer layers of the star which were lagging behind now fall violently onto this hard neutron core causing an enormous generation of heat. The surface of the core is heated to hundreds of billions of degrees for a fraction of a second. The collision of the high energy photons that are produced result in electron - positron pair creation. These in turn collide thereby annihilating themselves to form neutrino - antineutrino pairs. Neutrinos, which are massless particles like photons, are very unreactive with ordinary matter. For example all but one in a billion neutrinos emitted by the nuclear reactions in the center of the sun pass unhindered through it into interstellar space. However due to the enormous densities encountered in our collapsing star the neutrinos travel only very short distances before scattering off the collapsing material. Consequently they diffuse outwards losing much of their enormous energies and heating the outer layers of the star to tens of billions of degrees. These temperatures produce such high pressures that the collapse of the outer layers is reversed. The outer layers eject explosively, once again producing a supernova.

Whichever way it is produced, one such supernova explosion should be observed each year in 10^{14} stars. This means that in our own galaxy we should observe one about every three centuries. On July 4, 1054, for example, Chinese astronomers observed a supernova explosion that lasted for almost a year. The luminous remnant of the star's outer layers are seen to this day as the beautiful Crab Nebula. Now several light years across, the nebula is still energetic enough to emit radio waves, X rays and visible light. Within our own time, Astronomers have observed and studied tens of supernovae explosions in distant galaxies.

If our ideas are correct then deep within some supernovae there should be collapsed neutron cores which we call neutron stars. Calculations indicate that their masses lie between one - fifth and two solar masses and are packed into spheres having diameters between about 10 and 500 miles. During the first few seconds of their lives they should emit as much energy in gravitational waves and neutrinos that a star emits as light and heat in its entire normal life time. For several thousand years a neutron star should be a brighter source of X-rays than the sun is of lighter, and it will take millions of years before its surface cools down to a few thousand degrees.

In August 1967 Astronomers at the Mullard Radio Astronomy Observatory at Cambridge detected strange signals - radio - wave bursts spaced with such perfect regularity (one every 1.33730109 seconds) that it was even seriously considered that these may be the communication beacons of an advanced extra-terrestial civilization.

By now we know with considerable confidence that the radio bursts from pulsars are natural. They probably come from rapidly rotating neutron stars that beam narrow pencils of radio waves on our direction once or twice during each rotation period. It is not difficult to understand why neutron stars spin so rapidly. Most stars have rotation periods of the order of a few days. But should they shrink from their normal size to the size of a neutron star, conservation of angular momentum implies that they should spin with periods of the order of a fraction of a second. The difficulty is not to understand why they are spinning so rapidly but rather why they are not spinning even more rapidly! The reason is that we are not seeing the neutron stars immediately after formation but perhaps several thousand years or so later. In the absence of nuclear transformations and gravitational contraction, the energy continually radiated by the neutron star must be ultimately derived from its rotational energy. Consequently there is a gradual spin - down of the rotation.

At the present time almost a hundred pulsars have been observed. The most rapidly rotating pulsar, to date, lies in the heart of the Crab Nebula. It, like the nebula, is a remnant of the supernova explosion observed in 1054 A. D. This pulsar, which is the one studied most intensively thus far is now known to beam not only radio waves but also visible light and X-rays.

It should be added in passing that the term 'Pulsar' is really a misnomer. 'Rotator' would be a more appropriate name.

Gravitational collapse of a star does not always result in a white dwarf or a neutron star. If the star is more massive than two solar masses the collapse cannot be arrested at any stage.

The increased mass strengthens the gravitational attraction sufficiently to overwhelm even the strong repulsive force between neutrons. A catastrophic collapse occurs which makes the star so compact (about a couple of miles in radius) that even light can no longer escape its intense gravitational pull. In otherwords, the star creates and plunges into a 'black hole' in space.

Black holes cannot be understood within the framework of Newton's laws of gravitation. Gravity is so strong near a black hole that these laws break down and have to be replaced by the laws of General Relativity theory, which Albert Einstein formulated in 1915. Although the problem of relativistic gravitational collapse was first formulated and studied over thirty years ago by Robert Oppenheimer and Hartland Snyder, their work was considered to be of little or no relevance to astrophysics and remained in comparative obscurity. In 1963 that attitude changed suddenly. Quasi-stellar - radio sources, or quasars, had been discovered and the difficulty of explaining their enormous outputs of energy forced astrophysicists to consider collapse as the most likely source of energy.

Within a few years hundreds of theoretical physicists had converged on the problem from a variety of directions - relativity theory, nuclear physics, plasma physics, high energy physics, and magnetohydrodynamics. As a result of recent research, it is evident that the collapse cannot be halted if the neutron core is more than two solar masses. In fact relativity theory predicts that, from this point on, any resistance - no matter how large - will itself generate a still larger gravitational pull. Gravity inevitably wins. It crushes the entire star through the black hole down to infinite density. A region forms in space and time inside the black hole that has zero volume and posseses infinitely large gravity at its boundary. This is called a singularity to space - time. Within it is the entire collapsed star.

How near the singularity dare one approach before one would be captured forever by its gravity? The point of no return, called the gravitational radius, is the edge of the black hole itself.

It will be impossible for an observer to see the singularity of a collapsed star because no light ever escapes from the black hole. He may see the collapse, however. The star would be seen to collapse rapidly at first but as the star nears its gravitational radius photons take successively longer times to traverse the rapidly stretching space in the vicinity of the black hole. The collapse will thus appear to the observer to slow down. No matter how long the observer waits he will never receive light emitted after the star falls into the black hole. He will always - at least in principle be receiving the last few photons emitted from just outside it. The collapse will grind to a halt at the gravitational radius, and the star will hover there turning redder and darker until it will be virtually black and invisible. Only its intese gravitational field will be left. Of course this "winking out" of the star would usually be hidden from the observer by the luminous outer layers ejected by the star before plunging into its black hole.

The strong gravitational fields of black holes may however help to reveal their existence. Most stars are not single like the sun, but occur in pairs (binary systems) revolving around each other. It is possible that some of these binaries contain black hole components. An optical astronomer looking at a binary component will see a periodic shift in its spectral lines as it moves in its orbit alternately towards an away from him. Over 800 such spectroscopic binaries have been studied by astronomers to date. In a majority of these the companion star has also been 'seen' by means of the opposite shift of its own spectral lines. In about 300 cases the companion star is unseen. In most such 'single line binaries', as they are called, the unseen component is probably a small, normal star whose light pales in the brilliance of its larger companion. But in about 10 cases the spectral shift of the lines indicate that the unseen star is more massive than the visible component - between about 1.5 and 25 solar masses. Of course it is possible that the dark, massive component is a newly evolving star, but it has been argued by two American astrophysicists, Cameron and Stothers, in separate papers appearing in 'Nature' very recently, that this is most unlikely in the case of the binary systems known as epsilon Aurigae and 89 Hercules. In both cases it has been strongly argued that the unseen components are in fact black holes. Till further confirmation is available, however, it is wise to reserve judgment on these claims. Further, while both general relativity theory and its only competitive gravitation theory at present the scalar-tensor theory, developed in 1961 by American physicists Dicke and Brans - both predict an identical end to the collapse - the formation of a singularity, we do not know if these theories too would break down at the enormous densities encountered near these singularities. Thus a star may conceivably avoid the singularity although it is crushed into its black hole.

The problem is further complicated by the fact that real stars are not perfect spheres. As they collapse their deformations should grow. Although the relativistic collapse of idealized spherical stars is now fairly well understood, theoretical physicists are only beginning to make headway in understanding how deformations will effect the collapse. The most significant result in this connection is due to Roger Penrose, a British physicist. Making reasonable assumptions, he has shown that once a star collapses into its black hole, no deformation whatsoever can prevent it from creating a singularity. In spherical collapse, the entire star must be crushed into the singularity. in non-spherical collapse, however, although a singularity is created once again, a part of the star may avoid being crushed into it. This conclusion has been supported by the work of the Russian physicist Novikov. Novikov has also reached the surprising conclusion that the star which collapsed into the black hole would not remain at the same point in space, but would have to burst forth at some other distant point in the universe or even in some universe different from our own! The deformed black hole acts as a sort of "wormhole" to sweep matter from one region of space and time to another. Novikov and the Israeli physicist Neeman have speculated that quasars might be the explosive re-emergence of massive collapsed stars.

No external observer will ever be able to see into the blackness within the gravitational radius of a collapsed star. The events that theoretical physicists predict would happen there, can almost never be observed. I say almost never, because there may be at least in principle a unique possibility of observing gravitational collapse from within. The gravitational collapse of a star is but a trifling preview of

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The Flight of the Boomerang

K. H. ABEYWICKRAMA

FIRSTLY, yes the title was inspired by "The flight of the bumblebee" by Nicolas Andreievich Rimsky - Korsakov. It was not only the similarity in form of the titles, but the music too, in parts, could be mistaken to represent a not too sober boomerang doing it's rounds. An alternative title considered was "Making Boomerangs - Including all practical difficulties; Excluding all seriousness".

Getting down to boomerangs, it was rather perplexing how a stick, shaped something like an arm with a bent elbow (the type which could be no-balled for throwing) could apparently defy the laws of linear momentum, and get away with it without the matter being raised in the Royal Society or at least the C. A. A. S. After some initial experiments - with pieces of hard-board which were approximately the shape of the classical boomerang - which failed to give the desired results, I had almost abandoned the idea when I came across some research on boomerangs which gave quite a reasonable explanation for the trajectory of a boomerang (no laws being broken).

The essential points were the shape of the boomerang, and the manner of throwing.

Shape - all that was necessary was that one side should be convex with respect to the other, (hard-board won't do!), that is, like an aeroplane wing, where the top is convex, and almost flat below. The classical boomerang is something like two aeroplane wings joined at the centre with both flat sides on the same side and the wings making an angle 80 to 140 degrees at the centre. This classical shape is not indispensable, it could even be like a cross with equal arms, or many other shapes, provided the convex condition holds. To make a boomerang usable by both right and left handers, make the curvature of the curved side symmetrical about the centre line of each arm. This will make explanations a little easier but the performance should, theoretically be poorer (don't ask me for proof). (1)

Now, throwing - hold the boomerang by one of its arms in a vertical plane or slightly inclined to the right, with the flat side away from you. Throw it forwards - edge first - checking your throw just before releasing the boomerang, so as to make it spin in its plane. The direction of the throw should be horizontal or slightly upwards. Then the boomerang is supposed to go forward at about 60 m. p. h., while rotating at about 10 r. p. sec. (=w, say). (2)

Well, if all went well you should have it back in your hands in aprox. 10 seconds.

Whether it did come back or not, perhaps you might like an explanation as to why it ought to. Think of the centroid, G, of the boomerang moving forward with velocity, say u, at some instant of time, say t. At that same instant t, since the boomerang is spinning, a point on the upper arm would be moving forward, and a corresponding point on the lower arm would be moving backwards, with respect to G, with velocity, say v.

Thus, with respect to the earth, the upper point has a velocity $u + v$, and the lower point a velocity of $u - v$. This applies to all such pairs of points on the boomerang. Perhaps you might know about the effect which gives the lift to an aeroplane wing, corresponding to its velocity. (3) If you don't no matter, you see, aeroplanes are supposed to fly because of this

(1) If you must have one try: Theory of wing sections: including a summary of Airfoil data (1949). I. H. Abbott and A. E. von Doenhoff.

(2) Details of throwing and the theory are given only briefly here, full details can be found in: The Aerodynamics of Boomerangs. Frank Hess; Scientific American (Nov. 1968).

(3) If you wish to know more about it, try the book in (I) or: Theory Of Flight-R. von Mises et al., (1945) Aerodynamics - Theodore von Karman (1954)

lift, and any effect able to lift a jumbo-jet, should do something to a boomerang which, you might have noticed, is considerably smaller in weight.

Since the velocities of the arms are different, so are the lifts, hence there arises a torque, perpendicular to the direction of spin.

Now think of the spinning boomerang as the familiar spinning bicycle wheel. Apply a torque perpendicular to the spin. The wheel simply turns. (If you aren't familiar with bicycle wheels and how it takes a corner, I'd be glad to lend you my bike.)

So, theoretically the boomerang will turn left - if you throw it with your right hand, otherwise vice versa - go 360 degrees and then, to you.

The invisible mischief maker who was responsible for the 'return to sender' effect was apparently the air! As the world gets more civilized boomerangs ought to return better. For, whatever environmentalists and ecologists may say of pollution, it helps boomerangs to return - by increasing the density of air.

BI was the first boomerang I constructed. I took great care in making it, sand-papered silken-smooth till finally it was almost like something by Michelangelo Buonarroti. When it was thrown, - it went dead straight.

It was thrown a few times more (linear motion again and again) before it was noticed that it didn't spin! Finally it was concluded that this was because the angle between the arms was too great - it was about 160 degrees.

B2. The next was made with the angle about 90 degrees. On its inaugural flight it had an unexpected and unpleasant encounter with a member of the set classified as Cocos Nucifera. Since B2 did not survive this sad confrontation, it was decided that in future tests were to be carried out in open fields (the type which contains grass, not those found in Algebra), where boomerangs were unlikely to meet coconut trees (or any other trees for that matter). Broken boomerangs are not without use; the remains of B2 were picked up by somebody, and then used as guided missiles to bring down the fruit of a Spondias Mangifera. (I'm told they are equally effective on other fruit trees, but I have not ventured to test the truth of that statement).

B3 turned, but only about 25% of a circle and then made a soft landing (on Earth). A few more similar yet not so successful throws followed. Then B3 was thrown again, this time it was a crash landing. B3 split along the grain.

To overcome splitting along the grain, B4 was a cross - boomerang. B4 did turn, but in a direction opposite to that which was predicted! Further, it was noticed that B4 stopped spinning just before it fell down (stops spinning, then just pauses in mid air, as if flouting gravity for a brief moment - then nose dives). This was thought to be because of the moment of inertia, say C, not being great enough to sustain the spinning. C could be increased by attaching pieces of wire or tin-foil to the arms of B4.

When suitable strips of metal had been added to B4, the following results were obtained after many trials, after which finally, B4 too gave up the ghost (an arm breaking off).

(i) When made very heavy, B4 took a straight course.

(ii) When it wasn't too heavy and the metal strips were on the edges (furthest from centroid) of the arms, the flight did upto 75% of a circle, and most important, the direction was the predicted one!

(iii) With the same weight as in (ii) when the metal was moved closer to the centroid, B4 seemed uncertain which way to turn. On one flight it first turned left, then decided against it, and then turned right!

(iv) When the metal was moved even more closer to the centroid, it resumed turning the 'wrong way'.

(v) Though there was a blowing which was sometimes strong, the above results should be free of errors due to being blown off course, since trials were conducted with, against and across the wind, and then the mean behaviour considered. Further it was found that 'turning the wrong way' was not due to the spin being in the wrong direction by any chance.

The following explanations could be contemplated.

(i) When very heavy, linear momentum overrides all other factors.

(ii) When the moment of inertia is just correct, probably the theory holds true.

(iii) and (iv) In view of (v) when the moment of inertia is not large enough to maintain the spinning, the torque is probably not large enough to overcome the other factors, like wake effects in the air etc. Hence other factors predominate and somehow makes the boomerang turn the wrong way.

B1 to B4 were a selection of the boomerangs that were made, none of which were as successful as B4.

Dr. Hess ends his article in the Scientific American by saying "The reader may decide for himself, whether or not he finds the agreement between theory and experiment satisfactory". Hence I shall try to discuss some points.

1. If a boomerang is so constructed as to conform with the necessary requirements of his theory, and if his theory is correct, then that boomerang should return. Yet, he says "Whether a given boomerang belongs to the return type or not, cannot always be inferred easily from its appearance." In fact some of the unsuccessful boomerangs I made, fully conformed to the necessities of the given theory.

2. The theory completely neglects wake effects (since they are extremely difficult to take into account) which is, Dr. Hess says "... a factor that is probably very important". They must be important, for (*a*) the trailing arm - the arm trailing at any instant - has to follow in the wake of the other arm and the air flow conditions that arm has to encounter are hence unknown; (*b*) the trailing arm will actually be going forwards w. r. t. the earth (4) thus the air-stream will be blowing against what should be the trailing edge of the wing profile (like an aeroplane trying to fly backwards) which will positively upset ideal airfoil calculations even further. (5)

3. The theory at first neglects the average force perpendicular to the plane of the boomerang due to the lift since "...in the ideal case any motion of the boomerang in a direction perpendicular to its plane is supposed to vanish." This sounds like saying that, when a stone, say P, is being whirled in a circle, at the end of a string, 'the tension in the string is neglected since any motion of P in the direction perpendicular to the tangent at P to the circle is supposed to vanish'. One only has to remove the string and see whether the stone will continue going in a circle!

Later, this leaving out is found to be unjustified and "The effect was taken into account by considering it to be a small disturbance of the ideal motion". The 'small disturbance' is not explained any further.

4. The velocity of rotation, w, is forgotten about - for path calculations - since from observations "...w... does not change appreciably during one flight". In the observations on B4 it was seen that w does change, and in fact in the case of B4, ceases altogether!

These, together with the fact that most of even Australian boomerangs do not return, suggest that Dr. Hess's theory is true when certain ideal conditions other than those mentioned - are satisfied, but, the theory is not yet quite complete.

That it is on the right track, is amply shown by the amazing similarity (if not identicalness) of the trajectories based on his theory, calculated by computer and some of the photographed actual paths, given in his article.

That it is not quite complete, must surely follow from at least the fact that B4 turned in the direction opposite to that which the theory predicts.

The simplest explanation has been saved till the last. That is; I've made a mistake somewhere! This is quite possible, since I do not have much experimental data.

Meanwhile, B5 is being thought of, this time out of plywood, but, it is very likely to remain in the thinking stage for quite a while yet !!

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(4) Based on the facts that u=60 m. p. h. and w= 10 r. p. s. a simple calculation shows that if (u-v) is negative, the arms of the boomerang ought to be over 1.5 feet long. Hence it is positive, i. e. the lower arm too moves forward with respect to the earth.

(5) This is for airfoils, with blunt leading edge and sharp trailing edge etc., unlike the simple both edges alike one that I've described to make things easier and shorter.

ELEMENTARY PARTICLES

Dr. V. K. Samaranayake

ONE may say that Elementary Particle Physics deals with the most fundamental problem in physics—the theory of matter or the search for the 'basic stuff' of the universe, once thought to be water, fire, air and earth. The present day approach to the theory of matter takes us to the particle aspect of matter and their forces of interaction. It is interesting to note the similarity between the present day thinking and the following statement of Newton.

"Now the smallest particles of matter may cohere by the strongest attractions and compose bigger particles of weaker virtue and many of these may cohere and compose bigger particles whose virtue is still weaker, and so on for diverse successions, until the progression ends in the biggest particles on which the operations in Chemistry and the colours of natural bodies depend, and which by cohering compose bodies of sensible magnitude.

There are therefore agents in nature able to make the particles of bodies stick together by very strong attractions. And it is the business of experimental philosophy to find them out."

Although Newton knew only of the force of gravitation between particles, his statement is equally valid today. We will briefly discuss here the progress made by physicists since Newton, in this direction. In the nineteenth century it was thought that all matter in the universe was made up of different types of elements and each element could be subdivided into atoms. The periodic table of atoms more or less summarised Chemistry. Atoms were believed to be indivisible. It was found that atoms attracted each other when they were close and that this force was responsible for forming molecules out of atoms. At this stage atoms were considered the 'elementary particles' and the atomic force the elementary interaction.

In 1891, Lord Kelvin addressing the British Association for Advancement of Science said—

"We have discovered in physical sciences all that can be discovered. The rest is more and more refined measurement."

However in the same year a new revolution in physics took place. J. J. Thompson split the atom after thirty odd years of attempts by him and Rutherford at Cambridge. Thus the nice, simple, convenient world built of atoms was blown up and the basic stuff of the universe became the electron, the proton and the neutron. Atoms were found to have a core called the nucleus containing protons and neutrons and the electrons were found to orbit around the central core similar to planetary orbits around the sun. The atomic number in the periodic table corresponded to the number of electrons in each atom. The electrons and protons were given equal but opposite electric charge and the attraction between opposite charges explained the electron orbits. The neutron was considered to have no charge. There remained, however, many unsolved problems such as the role of the neutron and the nature of the force that held the neucleus together.

The pioneers in Quantum Theory showed that certain physical quantities can exist only as integer multiples of certain basic units. A good example is electric charge which always exist as an integer multiple of a unit. It was shown that energy (for example, of an electromagnetic wave) can exist in only integer multiples of a basic unit. This was explained by postulating the existence of the photon which was responsible for electromagnetic radiation. Radiation was described as a stream of photons travelling with the velocity of light and as such the enrgy existed in units of photon energy.

The next breakthrough came with the prediction of the antiparticle by Dirac. His successful attempts at obtaining Quantum equations satisfying relativity theory led to two important concepts—that of intrinsic spin (that the electron has built-in spin) and of the existence of antiparticles. He predicted that corresponding to every particle, there exists an antiparticle with the same mass and spin but with opposite charge. He also predicted that when a particle and an antiparticle collide, they must disappear with the energy, momentum and angular momentum going into a photon. The antielectron (called the positron) was discovered in 1934 and the antiproton in the fifties.

The fact that the protons and neutrons were tightly packed inside the nucleus lead to the assumption that the force that keeps them together (nuclear force) was much stronger than the electromagnetic force. Since the electromagnetic force was explained in terms of the exchange of photons the question arose as to what the quanta (or carrier) of the strong interaction was. Yukawa in 1935 predicted the existence of three particles (one positively charged, one negatively charged and the third neutral) which would act as the carrier of the strong force. These particles were discovered by Powel in 1947 and are known as the pi mesons.

The improvement of experimental techniques and the construction of particle accelerators in the fifties made a tremendous impact on the progress of particle physics. Many new particles were discovered and a new era in the development of physics commenced. The large number of particles known necessitated some classification and the experimentalists more or less overtook the theoreticians in going deeper and deeper into the unknown.

During the time of Newton the only interaction between particles known to exist was gravitational interaction. Experimental data on the interaction of elementary particles lead to three other types of interactions. They were termed strong, electromagnetic and weak. Their strengths differ from one another. If we express the strength of the gravitational interaction as unity the strengths of the weak, electromagnetic and strong interactions would be 10^{29}, 10^{32} and 10^{34} respectively. Thus the effect of gravitational attraction on elementary particles is negligible.

The above interactions however do not take place between all elementary particles. Particles that interact strongly are called hadrons and others leptons. Electromagnetic interactions take place between charged particles. Each elementary particle can be specified by the following constants:

(i) Rest mass (equal to the energy of the particle in its rest frame)

(ii) Spin

(iii) Whether particle or antiparticle

(iv) Electric charge Q

(v) Baryon charge B

(vi) Hypercharge Y

(vii) Isotopic charge I ($Q=I_3+Y/2$)

(viii) Strangeness S ($=Y+B$)

All three interactions conserve energy, momentum, angular momentum, charge and Baryon charge. Strong interactions conserve in addition hypercharge and isotopic charge. These conservation laws follow from symmetry properties of the scattering mechanism as explained below. The assumption of Poincare symmetry (invariance of the scattering mechanism under space time translations and rotations) leads us to the conservation of energy, momentum and angular momentum. The conservation of Q, B and Y are due to the symmetries in the U(1) group structure and the conservation of isotopic charge due to SU(2) symmetry.

Let us consider a complete orthonormal set of states of a physical system denoted by $|m\rangle$. Assuming that the set is discrete, we have $\langle m|n\rangle=\delta_{mn}$. Consider a change of basis given by the linear transformation U giving a new set of states $|m'\rangle=U|m\rangle$ ($\langle m'| = \langle m|U^*$ where* denotes the hermitian conjugate of U). Now to preserve the orthonormality of the new states, we require $\delta_{m'n'} = \langle m'|n'\rangle = \langle m|U^*U|n\rangle$ giving us the result $U^*U = I$. Such transformations are called unitary. If we consider these transformations to be infinitesimal, we have $U=\exp(i\epsilon^j F_j) = I + i\epsilon^j F_j$ where the ϵ^js are the parameters of the transformations. The unitary rerequirements gives $F^*=F$ and $U^* = I - i\epsilon^j F^j$ The operators F_j (which are hermitian) are quantum obervables and are the infinitesimal generators of the group of transformations of which the matrices U are the unitary representions. If we consider the transformations to be the rotation of axes then the corresponding Fs are the angular momentum operators.

If we denote the initial and final states of a system by $|i\rangle$ and $|f\rangle$ respectively, then the probability amplitude for transition between the two states is given by $\langle f|S|i\rangle$. We define the S matrix as the matrix formed by all such elements. If the matrix is invariant under the transformations U, then $\langle f|S|i\rangle = \langle f|U^*SU|i\rangle$ for all $|i\rangle$, $|f\rangle$ giving us $S=U^*SU$. Since U is unitary this means that $SU=US$. In terms of the F_j's we have $SF_j - F_jS = O$ for all j.

A certain number of F_j' s can be diagonalised simultaneously. Considering F to be one such F_j, we have $F|n> = f(n)|n>$ and therefore $<f|SF-FS|i> = (f(i)-f(f))<f|S|i>$ assuming that $|i>$ and $|f>$ are eigen states. Since $SF-FS=O$ and $<F|S|i> \neq O$, we have $f(i) = f(f)$ showing that F is conserved in any allowed transition. We have thus seen that invariance of the S matrix leads to a conservation law.

Let us now consider SU(2) — the unitary unimodular group of two dimensions. This group is isomorphic to the group of rotations in three dimensions. As before we can represent the group by $U = \exp(i\epsilon^j I_j) = 1 + i\epsilon^j I_j$ where $I_1\ I_2\ I_3$ are the generators. Of these only one (say I_3) could be diagonalised and this would lead to the conservation of a quantum number. The generators can be represented by $I_j = \frac{1}{2}\sigma_j$ where σ's are the Pauli matrices:

$$\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad \sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad \sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

giving eigen values $\pm 1/2$ for I_3. The corresponding eigenstates can be given as

$$|\tfrac{1}{2}> = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \text{ and } |-\tfrac{1}{2}> = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

The observation that the neutron and proton have nearly the same mass and appear to play very similar roles in nuclear reactions suggested that they could be considered two states of the same particle. In the 1930's Heisenberg first introduced the concept of treating the proton and neutron as the same particle in two isotopic charge states, obtained from the the group structure of SU(2) shown earlier. He considered the two states to be the two eigen states of I_3 and labelled them by the values $\pm 1/2$ which (called the isotopic charge or isotopic spin) distinguishes one particle from the other. Using these basic states it was possible to obtain suitably symmetrised products to represent other particles forming other multiplets (such as the triplet with $I_3 = 1, 0, -1$).

Around 1960 a generalisation was made to include isotopic charge and hypercharge in a larger group—the unitary unimodular group of three dimensions SU (3). This group has eight generators of which two can be diagonalised and these represent the isotopic charge and hypercharge. The multiplets obtained from the group consisted of 8 or 10 members, according to the representations of SU(3). The known particles fitted in well and properties of the missing member of a multiplet of ten were predicted. In 1964 the discovery of the Ω^- particle confirmed the predictions and gave much encouragement to those using group properties in elementary particle physics.

Some attempts were made to combine the multiplets of SU(3) to form multiplets of SU(6) and also to use the group U(12). However the most interesting development leading from the success of SU (3) is the concept of Quarks. Gell Mann and Zweig proposed that the basic spinor for the SU(3) group should correspond to a triplet of quarks (p', n', λ') which together with their antiparticles make up all other particles. This means that what we call elementary particles today would cease to be elementary and we are again reminded of Newton's statement. Much work has been done using the quark model and is quite a popular field of research now. As particles could now be considered neucleii made up of quarks, the techniques of nuclear physics are being used in particle physics now.

The major problem with quarks is that free quarks have not been observed directly, thus making the use of the quark model a purely theoretical exercise. In fact physicists are not quite sure where they should look for quarks, Cosmic rays seem to be the most probable place to find them. A claim made less than two years ago by an Australian group of the discovery of a quark has not been confirmed or accepted.

Recently, Feynman has introduced a new concept—that of Partons. He and others have conjectured that the nucleous consist of point like particles, when looked at in a frame of infinite angular momentum.

Theoretical activity in particle physics which reached a climax in the sixtees has now slowed down. Experimentalists are reaching higher and higher energies with their large multimillion dollar accelerators, but without any sensational results. The discovery of a quark (if there are such fundamental particles) would certainly give particle physics the shot in the arm it certainly needs at the moment. On theoretical problems what we need is a completely new approach—a new way of thinking. For that we are waiting till another Einstein is born!

GOD AND EINSTEIN

BY ARTHUR C. CLARK

FOR some years I have been worried by the following astro-theological paradox. It is hard to believe that no one else has ever thought of it, yet I have never seen it discussed anywhere.

One of the most firmly established facts of modern physics, and the basis of Einstein's Theory of Relativity, is that the velocity of light is the speed limit of the material universe. No object, no signal, no **influence**, can travel any faster than this. Please don't ask why this should be; the universe just happened to be built that way. Or so it seems at the moment.

But light takes not millions, but **billions**, of years to cross even the part of Creation we can observe with our telescopes. So: If God obeys the laws He apparently established, at any given time He can have control over only an infinitesimal fraction of the universe. All Hell might (literally?) be breaking lose ten light-years away. Which is a mere stone's throw in interstella space, and the bad news would take at least ten years to reach Him. And then it would be another ten years, at least, before He could get there to do anything about it......

You may answer that this is terribly **naive** that God is already "everywhere." Perhaps so; but that really comes to the same thing as saying that His thoughts, and His influence, can travel at an infinite velocity. And in this case, the Einstein speed limit is not absolute; it **can** be broken.

The implicatlons of this are profound. From the human viewpoint, it is no longer absurd - though it may be presumptuous - to hope that we may one day have knowledge of the most distant parts of the universe. The snail's-pace of the velocity of light need not be an eternal limitation, and the remotest galaxies may one day lie within our reach.

But perhaps, on the other hand, God Himself is limited by the same laws that govern the movements of electrons and protons, stars and spaceships. And that may be the cause of all our troubles.

He's coming just as quickly as He can, but there's nothing that even He can do about that maddening 186,000 miles a second.

It's anybody's guess whether He'll be herse in time.

On Relativism and Human Values

J. Satchithanandam

The theory of relativity has brought with it, more than any other physical theory in recent times, certain new concepts hitherto unfamiliar to man and certain other concepts which are an affirmation of already existing beliefs. Attempts have been made, not unjustifiably, to extend and apply these concepts to other fields as well, such as morality, politics and religion. There is a widespread belief that according to Einstein "everything is relative", and this belief has affected not only particular systems of thought and conduct but more generally our conception of truth itself. To this belief I shall give the name relativism.

By relativism then, to be more explicit, I mean the doctrine which holds that any judgment that one could make is necessarily related to certain arbitrarily chosen hypothesis or assumptions and the point of view of the observer who makes the judgment. Here I propose to examine the doctrine itself and also its applicability to those concepts or systems of concepts which influence human behaviour.

Relativism in science has its origin when Leibniz and Berkely attacked Newton's postulates of absolute space and time. But it acquires prominence only after the penetrating criticisms of Newton's theories by Ernst Mach. And it reaches its climax when Einstein puts forward his special theory of relativity.

But few people realise that the theory of relativity as its stands today is not what Einstein intended it to be. Einstein who was tremendously influenced by Mach began with his principle of relativity according to which the laws of physics cannot depend on the accidental choice of our frame of reference. This is based on the fundamental belief that motion is meaningful only in so far as it is related to a frame of reference. In turn it implies that there is no privileged frame of reference thus strengthening the doctrine of relativism. But on the other hand, in it is implicit the belief in an objective would and its relations which are independent of us and the particular means by which we study them. Apart from this, careful investigation shows the presence of a space-time continuum, which contrary to Einstein's original intentions play a fundamental and absolute role contradicting the spirit of relativism.

More generally speaking, the human mind is not capable of constructing, on its own, any conceptual system - even without a correspondence with reality - which is free from absolute concepts. By an absolute concept here, I mean a concept which cannot be questioned within the frame-work of the theoretical system which we have adopted. In fact any logical structure whether in science or in any other field of human activity is necessarily based on certain hypotheses and makes use of certain undefinable objects and irreducible rules. A system of concepts in which everything is relative in the sense that each concept is related to some other concept will be a conceptual anarchy and a perfect chaos.

If we pay attention to any one particular concept we would find that it is related to other concepts and has meaning only in relation to them. An idea considered in complete isolation is meaningless. It acquires meaning only when it is properly related to other ideas. But on considering the entire conceptual system, we find certain concepts which lie at its base, on which the entire system rests and which are absolute on this account. I call them absolute because they are not relative in the usual sense of the word; even though they have to be taken for granted, they cannot be questioned and are irreplaceble unless one wishes to do away with the entire system. Actually we are not even capable of constructing a system which is free from absolute ideas or concepts not to speak of the correspondence with reality which it may have. Any conceptual system has to begin with certain absolute objects and certain absolute rules or axioms.

So it is also with an ethical system. But here what usually happens is that when one is confronted with a particular situation one forgets the underlying system and with that certain ethical ideals which manifest their absolute character only when viewed as an integral part of the entire system.

Relativism, to my mind, derives its greatest strength from the philosophy of logical positivism (sometimes known as "operational procedure"). This was first put forward by Mach but it became famous only after its applications by Einstein. According to Mach a word has meaning only if it can point to the object to which it refers. A statement is meaningless unless it can be verified by sense- experiences or expressed in terms of actually occurring events. This philosophy proved to be very powerful in science. It eliminated certain metaphysical notions in Newtonian physics and paved the way for the theory of relativity thus providing an effective answer to those who ask "after all, what is the use of philosophy?"(1) Although Einstein used this philosophical method consciously as was demanded by the complexity of the problem that confronted him, this method has been used unconsciously by other scientists in other fields in the solution of simpler problems. Thus in biology, for instance, Lamarck's theory of evolution was rejected in favour of Darwins' theory because the former involves the inheritance of acquired characteristics which does not satisfy the positivistic criterion of truth. But Darwin's theory of evolution by natural selection satisfies it since it can be expressed in terms of physically meaningful events. In chemistry too one could legitimately ask whether the resonance structure of the benzene ring and other molecules satisfy the positivistic criterion of truth. Here a partial answer can be given by regarding the molecular structure as a quantum mechanical situation. In morality too it had drastic consequences. For according to positivism, "good" and "evil" are meaningless terms and at most are expressions of the state of mind of the person who is expressing them. All moral and ethical propositions, according to positivism, are subjective since our emotional experiences are the only reality on which they can be based. They are meaningless unless they are modified so as to include a reference to our sentiments.

The fundamental difference between science and ethics is that while science is concerned with what **is**, ethics is concerned with what **ought** to be. But according to the positivist while 'is' has meaning, 'ought' has no meaning. For instance, the statement that the moon revolves around the earth is meaningful and true since it can be verified by means of sense-experiences; but the statement that the moon ought to revolve around the earth has no meaning since it cannot be verified and is not even verifiable. Likewise when a man commits a certain act, the fact that he does commit the act is meaningful since it is verifiable and is true since it can be verified. But whether he ought to have done it or not is by itself meaningless since it cannot be verified in terms of actually occurring events in space and time. Thus at best such a statement can only be regarded as a deduction from some arbitrary chosen postulates or assumptions. It is related to these assumptions. Hence it is relative since if we started with different axioms we would have arrived at different conclusions. But a basic flaw in this argument is that it does not take into account the fact that human beings, unlike inert matter - are free to a large extent to do what they want. Therefore they are responsible for their actions and the consequences of these actions. This responsibility cannot be avoided unless one denies free - will in the first place in which case of course all our actions are predetermined, we have no control over them and the entire question of relativism is irrelevant.

Once we recognise this freedom of action the question naturally arises as to how we could organize our thought and conduct in order that we would live a harmonious life. To do so one must begin with a conceptual-system which must be self - consistent and also comprehensive enough to guide us in the totality of our experiences. Such a system is necessarily based on hypotheses and concepts which may or may not correspond to objects or events of the material would. In this respect ethics does not fundamentally differ from science. For science too begins with certain postulates the only justification for which is that they conform to and make comprehensible the totality of our experiences. As Einstein says "The only justification for our concepts and systems of concepts is that they serve to represent the complex of our experiences; beyond this they have no legitimacy. ...even if it should appear that the universe of ideas cannot be deduced from experience by logical means, but is, in a sense, a creation of

(1) To quote Einstein, "I can say with certainty that the study of Mach and Hume has been directly and indirectly a great help in my work.... Mach recognized weak spots of classical mechanics and was not very far from requiring a general theory of relativity half a century ago........"

(Physikalische Zeitschrift, 1916)

the human mind, without which no science is possible, nevertheless this universe of ideas is just as little independent of the nature of our experiences as clothes are of the form of the human body. "(2)

The concepts we use are invented by us. It is not therefore always possible or necessary to relate our concepts directly to experience as is demanded by the operational philosophy. The world of concepts is necessarily separate from the world of experience. Einstein says, "I am convinced that.... the concepts which, arise in our thought and in our linguistic expressions are all when viewed logically the free creations of thought which cannot inductively be gained from sense - experiences. This is not so easily noticed only because we have the habit of combining certain concepts and conceptual relations (propositions) so definitely with certain sense experiences that we do not become conscious of the gulf - logically unbridgeable - which separates the world of sensory experiences from the world of concepts and propositions (3)".

Nevertheless the operational procedure can play a very useful role in ethics. Superstition plays the same part in ethics which metaphysics played in physics. The operational procedure by relating our concepts to experience could eliminate superstitions that now underlie morality in the same way it eliminated sterile metaphysical notions in physics.(4) Ethical values which guide us in the attainment of immediate goals with a view of some ultimate goal must grow organically from our experiences and on no account should be separated from them. **Authoritarianism and dogmatism which have been the characteristics of organised religions, by imposing a particular world-view on us, have had a harmful effect which can only be removed by the realisation that whatever world-view we have must ultimately be linked with experience.** They must not be introduced under the guise of religious "revelations" to be accepted as everlasting truths.

The entire mass of scientific knowledge consists of concepts freely invented by man to make himself at home with nature. If our personal experiences compel us to invent ethical concepts, logically speaking, they cannot be subject to any serious criticism just because their underlying ideas transcend our sense - experiences. But on the other hand such concepts must eventually depend on our experiences for their legitimacy. They must be modified if our experiences were to demand such a modification. To quote Einstein "It is the privilege of man's moral genuis impersonated by inspired indivduals, to advance ethical axioms which are so comprehensive and so well founded that men will accept them as grounded in the vast mass of their individual emotional experiences. Ethical axioms are found and tested not very differently from the axioms of science. *Truth is what stands the test of experience*".(5)

In conclusion we may state that whatever conceptual system we construct is absolute for two reasons. Firstly because it has to apply to the relations between objects of the real world which exist independent of us and are absolute on that account. Secondly because it is necessarily based on certain fundamental (absolute) hypotheses. On the other hand it is relative, also for two reasons. Firstly because the chosen hypothesis are arbitrary; as Einstein says they are free creations of the human mind. Secondly because the description of the system involves concepts which derive their meaning and truth-value through their relationship to other concepts and which have no legitimancy beyond that. What is absolute is relative, and what is relative is also absolute. This is true in science as well as in ethics. A realisation of this would contribute towards a saner attitude towards morality and also life in general.

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(2) 'The meaning of Relativity' p 2.

(3) Remarks on Bertrand Russell's Theory of Knowledge.

(4) Einstein who was himself influenced to some extent by the operational procedure says, "In order that thinking might not degenerate into 'metaphysics' or into empty talk it is only necessary that enough propositions of the conceptual system be firmly enough connected with sensory experiences and that the conceptual system, in view of its task of ordering and surveying sense - experience, should show as much unity and parsimony as possible. Beyond this however, the "system" is (as regards logic) a free play with symbols according to (logical) arbitrary given rules of the game. All this applies as much (and in the same manner) to the thinking in daily life as to the more consciously and systematically constructed thought in the sciences" ('Remarks on Bertrand Russell's Theory of knowledge').

(5) ' The Laws of Science and the Laws of Ethics-Einstein's Forward to 'Relativity - A Richer Truth' by P. Frank. The italics are mine.

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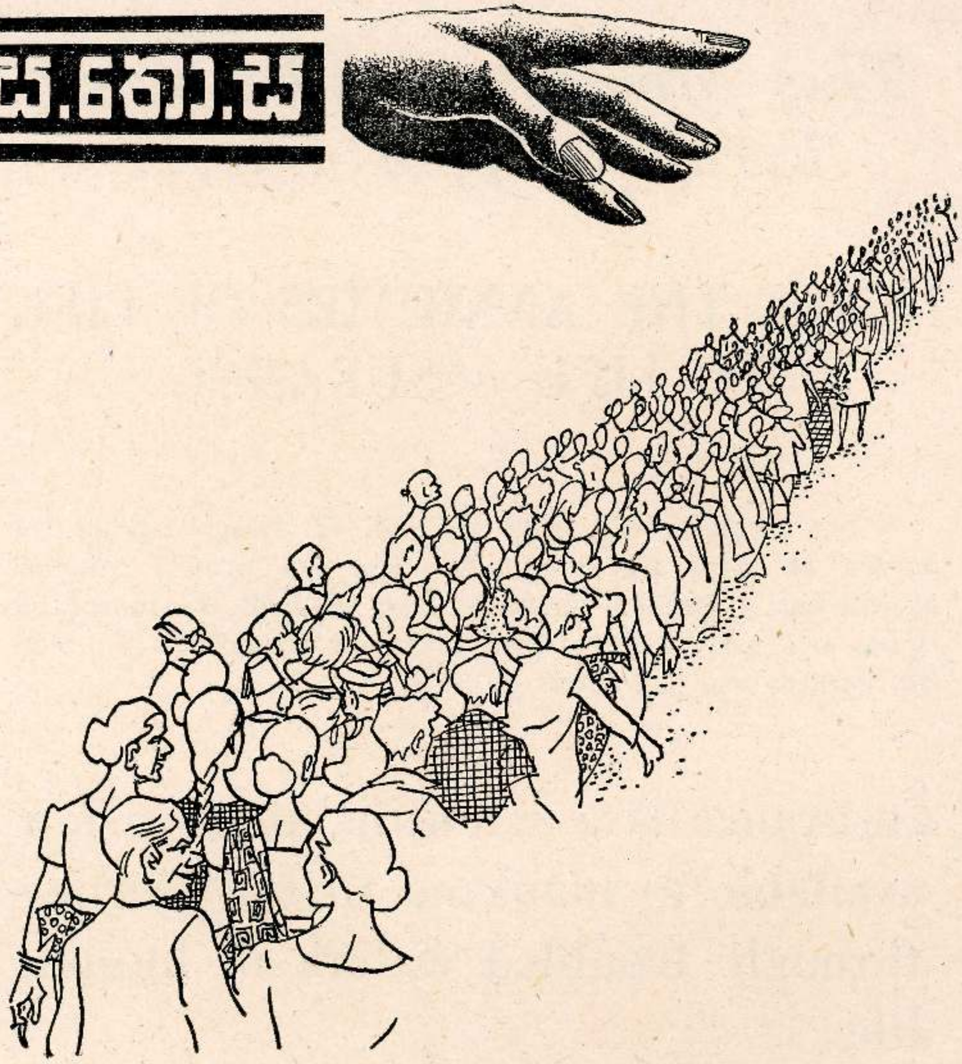

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ජීවය දෙස විද්‍යාත්මක බැලීමක්

ම. ගා. මාරසිංහ

අපේ ග්‍රහ මණ්ඩලයේ වෙනත් ග්‍රහ ලෝකවල ජීවය ඇත්ද? විශ්වයේ වෙනත් ස්ථාන වලත් ජීවය තිබිය හැකිද? එසේ නම් එම ජීවීන් පෘථිවි ජීවීන් හා සමානද? මෙවැනි ප්‍රශ්න සඳ ගමන් අරඹා ඇති මේ අවධියේ අපට නිතර අසන්නට ලැබේ. මෙම ප්‍රශ්නයන්ට විද්‍යාඥයන් දෙන පිළිතුර පැහැදිලි වීමට නම් පෘථිවියේ ජීවය පිළිබඳ ඔවුන් ඉදිරිපත් කරන ඇති මත පිළිබඳ වැටහීමක් අවශ්‍ය වේ.

ජීවය, එය සෑදී ඇති අනු වල රසායනික හා භෞතික ගතිගුණ මවා පෑමක් ලෙස, අර්ථ දැක්විය හැකිමුත්, සජීව වස්තූන් අජීව වස්තූන් ගෙන් හඳුනා ගැනීමට මෙය උපකාරී නොවේ. සෛලය, මූලික ජීව විද්‍යාත්මක ඒකකය, ලෙස පිළිගෙන ඇතිමුත් අපට මේ ජීවය, මේ අජීවයයි සීමාවකින් වෙන් කොට ගැනීමට ස්වභාව ධර්මයා ඉඩ සලසා නැත. සියලුම ජීවීන්, සෛල එකකින් හෝ වැඩි සංඛ්‍යාවකින් සමන්විතය. මිනිස් සිරුර ද, එකිනෙකට සමාන වූ ගතිගුණ හා ව්‍යුහයන් ඇති සෛල කෝටි ගණනකින් යුක්තවේ. බැක්ටීරියා වැනි ක්ෂුද්‍ර ජීවීන් ද එවැනිම සෛලයකින් යුක්තය.

සෑම සෛලයක් ම එහි ක්‍රියාකාරිත්වයට අවශ්‍ය අණු පමණක් ඇතුළු කර ගන්නා පටලයකින් වටවී ඇත. සෛලය තුළ න්‍යෂ්ටිය (Nucleus) සෛල ප්ලාස්මය (Cytoplasm) හා මයිටොකොන්ඩ්‍රියා (Mitochondria) යනාදී පොදු ඒකක දක්නට ඇත. මේ ව්‍යුහාත්මක සමාන කම් හැරෙන්නට සෛලයන්හි රසායනික සංයුතිය ද බොහෝ දුරට සමාන වේ. ජීව වස්තූන් ප්‍රධාන වශයෙන් ප්‍රෝටීන්, මේද හා කාබොහයිඩ්‍රේට් (ප්‍රෝටීන් 15% මේද 5% කාබෝහයිඩ්‍රේට් 2% ජලය 77%) යන රසායනික සංයෝග වලින් යුක්තය. මේ සෑම සංයෝගයකම ව්‍යුහයේ කාබන් පරමාණුව ප්‍රධාන තැනක් ගනී. කාබෝහයිඩ්‍රේටයක් වූ ග්ලූකෝස් හි කාබන් අණු 6 ක් ඇත. ප්‍රෝටීන්, ඇමයිනෝ අම්ල අණු රාශියකින් සෑදුම්ලත් සංකීර්ණ අණු වලින් යුක්තය. ඇමයිනෝ අම්ලයද කාබනික සංයෝගයකි. සෛලයේ ජීව කොටස් හෙවත් ප්‍රාක්ප්ලාස්මය (Protoplasm) ප්‍රධාන වශයෙන් මූල ද්‍රව්‍ය හතරකින් සෑදී ඇත. එහි රසායනික සංයුතිය, ඔක්සිජන් 65%, කාබන් 18%, හයිඩ්‍රජන් 11% හා නයිට්‍රජන් 2% ක් වේ. විශ්වයේ වැඩිපුරම ව්‍යාප්තව පවතින මූල ද්‍රව්‍යයන් ද මේවා වීම සැලකිය යුතු කරුණකි. එමෙන් ම ග්‍රහලෝක සෑදීමට ආරම්භ වන අවධියේ එම ග්‍රහ ලෝකයන්හි වායුගෝල, වැඩිපුරම මෙම මූල ද්‍රව්‍යයන්හිම සංයෝග වන මීතේන් ඇමෝනියා හා ජලයෙන් යුක්ත වේයයි විශ්වාස කරනු ලැබේ.

සෑම ජීවයකගේ ම වැඩි විශයෙන් ම ඇති රසායනික සංයෝග ජලය වේ. ඉතාම වියලි සෛලයන්හි පවා 20% පමණ ජලය ඇත. සෛලයන්හි රසායනික ක්‍රියාකාරිත්වයට ජලය අත්‍යාවශ්‍ය යයි කිව හැක. එම නිසා දන්නා පරිදි ජීවය ඇති වීමට හා පැවැත්මට ජලය ඉතා අවශ්‍ය ම අංගයක් බව ජීව විද්‍යාඥයන් පිළිගෙන ඇත.

ඇමීබා වැනි ඒක සෛලික ජීවීන් දෙකට බෙදී සෛල දෙකක් උත්පාදනය කිරීම, (ප්‍රතිකෘතිය) සෑම ජීවයකටම පොදු ලක්ෂණයකි. මෙම ක්‍රියාවලියට අවශ්‍ය ශක්තිය, සෛලයන් මගින් රසායනිකව නිපදවා ගැනීමට පරිවෘත්තිය (Metabolism) යයි කියනු ලැබේ. මෙම ක්‍රියා වලිය ජීවීන් හඳුනා ගැනීමේ ප්‍රධාන ලක්ෂණයක් වේ. බැක්ටීරියා වැනි ක්ෂුද්‍ර ප්‍රාණීන්ට පවා චලනය වීමට හැකියාවක් ඇත. මෙයද ජීවීන්ට පොදු ලක්ෂණයකි. තවද, බාහිර උත්තේජ (External stimuli) හා පරිසර යේ වෙනස්වීම් වලට අනුකූලව, ජීවීන්ගේ ප්‍රතිචාරයක් (Response) ඇති වීම ද මෙවැනිම ලක්ෂණයකි. උදාහරණයක් වශයෙන් ආලෝකය, රසායනික ද්‍රව්‍ය, උෂ්ණත්වය යනාදිය බාහිර උත්තේජ ලෙස සැලකිය හැක. බැක්ටීරියා ඇති මාධ්‍යයක සාන්ද්‍රතාවය වෙනස් කිරීමෙන් අපේක්ෂිත ප්‍රතිචාරයක් ලබා ගත හැක.

උත්පාදක නව සෛලයේ ද මව් සෛලයේ ම ඇති ගතිගුණ ඇතිවීම, සෛල තුළ කිසියම් ක්‍රියාවලියක් නිසා සිදු විය යුතුය. සෛලයේ ලක්ෂණ හා ගතිගුණ පිළිබඳ තොරතුරු සමහර අණු මාර්ගයෙන් සෛලයේ න්‍යෂ්ටිය තුළ ගැබ් වී තිබේ. DNA යනුවෙන් හැඳින්වෙන මෙම අණුවල මව් සෛල හා සමාන සෛලයක් බිහි කිරීමට අවශ්‍ය තොරතුරු රසායනික වශයෙන් රැඳී ඇති බැව් විශ්වාස කරනු ලැබේ. මෙම අණු, සෛලයේ ආවේනික ද්‍රව්‍යය (Hereditary Matter) ලෙස හැඳින් වෙන අතර ඉහත සඳහන් ප්‍රතිකෘති ක්‍රියාවලියේ දී ප්‍රධාන තැනක් ගනී.

ප්‍රතිකෘත ක්‍රියාවලියේ සමහර අවස්ථා වලදී සිදුවන 'අතපසුවීම්' හෝ වැරදී නිසා, ගතිගුණ අතින් විකෘත වූ සෛල ඇති වීමට ඉඩ තිබේ. මෙසේ වීමට විකෘතිය (Mutation) යයි කියනු ලැබේ. එම අවස්ථාවලදී නව සෛලයන්හි වැඩීම රඳා පවතින්නේ එම පරිසරයේ, එහි පැවැත්මට අවශ්‍ය කරුණු සියල්ල අඩංගුවීම මතය. මෙලෙස එම පරිසරයේ ඉතිරි වන්නේ විකෘති සෛලයන්ගෙන්, එහි ජීවත් වීමට හැකියාවක් ඇති ජීවීන් පමණි. සත්ව විශේෂයන් (Species) ඇති වීමට මූලික හේතුව මෙය වේ. ඩාවින්ගේ සත්ව විකාශන වාදයේ ස්වාභාවික වරණය (Natural Selection) යනුවෙන් හැඳින් වනුයේ මෙම ක්‍රියා වලියයි. එම නිසා ඇත්ත වශයෙන් ම සත්ව පරිනාමයට මූලිකව හේතු වන්නේ සෛල විකෘතියයි.

පෘථිවියේ ජීවය ඇති වීමට පෙර තත්වය, ජීවය ඇති වීමට තුඩු දුන් හේතූන් හා ජීවය ඇති වූ ආකාරය ගැන කරුණු සෙවීම විද්‍යාඥයන් විසින් ආරම්භ කොට කලක් ගතවී ඇත. මේ පිළිබඳව ප්‍රථම මතය ඉදිරිපත් කර ඇත්තේ සෝවියට් විද්‍යාඥ ඇලෙක්සැන්ඩර් අයි. ඔපාරින් ය. සරල රසායනික මූල ද්‍රව්‍යයන්ගෙන් ජීවය ඇතිවූයේ යයි කියන එම මතයට රසායනික පරිනාම වාදය යයි කිව හැක. මේ පිළිබඳ විද්‍යාත්මක හැදෑරීම, ප්‍රාග් ජීව විද්‍යාව ලෙස හඳුන්වනු ලැබේ. ඔපාරින්ගේ රසායනික පරිනාමය සනාථ කිරීම් වස් පර්යේෂණ දූන් නොයෙක් පර්යේෂණ මධ්‍යස්ථාන වල කෙරී ගෙන යයි. පෘථිවිය ඇති වූවාට පසු මුලින් තිබූ මූල ද්‍රව්‍යයන්ගෙන් ජීවය ඇතිකිරීමට සමත් සංයෝග සෑදී පසුව ඒවා රසායනික පරිනාමයකට භාජන වී නිතැතින්ම ජීවය ඇතිවූයේය, යන මතය දූන් විද්‍යාඥයන් පිළිගෙන ඇත.

අනාදි තම යුගයේ, එනම් පෘථිවිය සෑදුන යුගයේ රසායනික වශයෙන් තත්වය රසායනාගාරයේ ඇති කිරීමෙන් එකල සිදු වූයේ යැයි සැක කරන රසායනික ප්‍රතික්‍රියා නැවත ඇතිකළ හැක. එමෙන්ම පෘථිවියෙන් ඔබ්බෙහි පිහිටි ග්‍රහ ලෝක හා පෘථිවියට පතිත වන උල්කාපාත මගින් එම වස්තු වලද රසායනික හා ජීව පරිනාමය සිදු වී තිබේද, එසේ නම් දැන් පවතින්නේ විකාශනයේ කුමන අවස්ථාවක ද යන්න නිර්ණය කළ හැක.

වර්ෂ 450 කෝටියක පමණ පෙර පෘථිවිය සෑදුණේ සූර්යයා සෑදුන ද්‍රව්‍යයන්ගෙන් ම නිසා මුලදී පෘථිවියේ හයිඩ්‍රජන් විශාල වශයෙන් පැවතුන බව නිසැකය. පසුව, පෘථිවියේ අඩු ආකර්ෂණ ශක්තිය නිසා එම හයිඩ්‍රජන් අවකාශයට විසිර ගියත් ජීව උපතට අවශ්‍ය කාබන්, නයිට්‍රජන් හා ඔක්සිජන් ඒවායේ හයිඩ්‍රජන් සංයෝග වන මීතේන්, ඇමෝනියා හා ජලය ලෙස ආදි වායු ගෝලයේ හා පෘථිවිය මත ඉතිරි වූයේ යැයි සැක කරනු ලැබේ. මෙලෙස ආදිම පෘථිවි වායු ගෝලයේ නිදහස් ඔක්සිජන් නොතිබුන අතර වායු ගෝලයට ඔක්සිජන් නිදහස් වූයේ ජීවීන් ගේ පරිවෘති ක්‍රියාවලි (Metabolic Processes) මගිනි.

ආදි පෘථිවියේ අද දක්නට නොලැබෙන ශක්ති ප්‍රභව කිහිපයක් තිබෙන්නට ඇත. පර ජම්බුල කිරණ ඉන් එකකි. මෙකල වායු ගෝලයේ ඉහළ පෙදෙස ඇති ඕසෝන් වායු තට්ටු ව නිසා අප ඒ කිරණයන් ගෙන් මුවා වී ඇත. දරුණු අකුණු කෙටිලි සහිත විද්‍යුත් සංඝට්ටනද ඉතා සුදුසු ශක්ති ප්‍රභවයක් වේ. විකිරණශීලි මූල ද්‍රව්‍ය වන තේරියම් හා යුරේනියම් ද ශක්ති ප්‍රභව ලෙස ක්‍රියා කරන්නට ඇත. ගිනිකඳු යනාදිය නිසා පෘථිවි තලයේ උෂ්ණත්වයද අධික විය යුතු ය. මුලින් සඳහන් කළ සරල සංයෝගයන්ගෙන් සංකීර්ණ කාබනික සංයෝග සෑදීමට මේ ශක්ති ප්‍රභව ඉවහල් වන්නට ඇතැයි දැනට කෙරිගෙන යන පරීක්ෂණ මගින් සනාථ වේ. මීතේන්, ඇමෝනියා, හා ජලවාෂ්ප හා හයිඩ්‍රජන් අඩංගු වායු මිශ්‍රණයක් හා ඉහත සඳහන් ශක්ති ප්‍රභවයක් නිසා ක්‍රියාත්මක වූ ප්‍රති ක්‍රියාවන්ගෙන් උත්පාදිත අන්තඵල ආදි මුහුදු වල එකතු වන්නට විය. මෙම පරිසරය අන්‍ය ප්‍රතික්‍රියාවන්ට බෙහෙවින් යෝග්‍ය නිසා, සංකීර්ණ අණු වලට තුඩු දුන් ප්‍රතික්‍රියාවන් සිදු වූ බව සිතිය හැක. මෙම ප්‍රතික්‍රියා වලියේ යම් අවස්ථාවක පෙර සඳහන් පරිදි ජීවය ඉපදීමට සමත් ගතිගුණ ඇති සංකීර්ණ අණු සෑදෙන්නට ඇත.

මෙම මත සනාථ කිරීම පිණිස පසුගිය වර්ෂ කීපය තුළ කරන ලද පර්යේෂණ අතුරින් සමහරක් ඉතා සාර්ථක විය. 1953 දී චිකාගෝ විශ්ව විද්‍යාලයේ දී, ආදි වායු ගෝලයේ තිබෙන්නට ඇතැයි සැක කරන ඇමෝනියා, මීතේන් ජල වාෂ්ප හා හයිඩ්‍රජන් වායු මිශ්‍රණයක් විද්‍යුත් විසර්ජනයකට භාජන කිරීමෙන් පසු ලද අන්ත ඵල අතර ඇමයිනෝ අම්ල රාශියක් දක්නට ලැබිණ. පෘථිවි ජීවයට අවශ්‍ය වන ප්‍රෝටීන් අනු, ඇමයිනෝ අම්ලයන් ගෙන් යුක්ත වන බැවින්, මෙම පර්යේෂණය අතිශයින් ම වැදගත් විය.

මෙම පරීක්ෂණය වෙනත් වායු ගෝලීය මාධ්‍ය හා ශක්ති ප්‍රභව උපයෝගී කර ගනිමින් නැවත නැවතත් අත්හද බලන ලදී. සෑම අවස්ථාවකදීම කාබනික සංයෝග රාශියක් නිපදවුනි.

තවද මෙම පර්යේෂණයේදී ඵලයන් වන ඇමයිනෝ අම්ල, වියලි තාපයට භාජනය කිරීමෙන් ප්‍රෝටීන් වැනි ද්‍රව්‍යයක් නිපදවීමට ද හැකි වී තිබේ. මේ ආකාරයෙන් ආදි වායුගෝලයේ තිබිය හැකි යයි සැක කරන වායු සංයුතියක් භාවිතයෙන් ජීවයේ මූලික කොටස් රසායනිකව නිපදවීමට හැකි වී ඇත. තවද මේ ආකාරයෙන් ම DNA හි කොටසක් වන ඇඩිනින් හශ්මයද, සෛලයන්හි ශක්ති මූලයක් වන ATP නැමැති ද්‍රව්‍යයක් ද විශ්ලේෂණය කිරීමට හැකි වී තිබේ. (ආචාර්ය පොන්නම්පෙරුම විසිනි.) එනමුත් මෙම පර්යේෂණයන්ගෙන්, වර්ෂ කෝටි ගණනකදී ස්වාභාවික සාර්ථක වූ ජීවයේ උපත රසායනාගාරයේ දී ඉතා කෙටි කාලයකදී අණුකරණය කිරීම උගහටය. පර්යේෂණාගාරයේ කෙරෙන මෙම රසායනික සංශ්ලේෂණය හැර, පෘථිවියේ ඔබ්බෙහි ජීවය පිළිබඳව ද පරීක්ෂණ කෙරී ගෙන යයි. අපේ ග්‍රහ මණ්ඩලයේ එක් එක් ග්‍රහයා ගේ ගුරුත්වාකර්ෂණය, චුම්බක ක්ෂේත්‍රය උෂ්ණත්වය, වායු ගෝලය හා රසයානික සංයුතිය යනාදිය පිළිබඳව වැඩි දුරටත් පර්යේෂණ පවත්වා ගෙන යනු ලැබේ.

තවද මෑතදී ලැබූ හඳේ පස් හා උල්කාපාත යනාදිය රසායනික විශ්ලේෂණයට භාජනය කිරීමත් දැන් ලොව පුරා සිදුවේ. මෙම පර්යේෂණ යන්හි සාර්ථකත්වය පිළිබඳව, මර්චසන් උල්කාපාතය හොඳ නිදසුනක් වේ. අවුරුදු කෝටි 450 ක් පමණ පැරණි යයි නිර්නය කරන මෙම උල්කාපාත කැබැල්ලේ තිබී වාම හා දක්ෂිණ වෘත (L-and D-Rotatory) ඇමයිනෝ අම්ල රාශියක් සොයා ගෙන ඇත. සාමාන්‍යයෙන් පෘථිවියේ දක්නට ලැබෙන්නේ වාම වෘත ඇමයිනෝ අම්ල අණු පමණය. මෙවැනි, විශේෂඥයන් පවා මවිත කරන සොයා ගැනීම්, අනාගත පරීක්ෂණ වලදී ද අනාවරනය විය හැකිය.

THE UNIVERSE: OLD AND NEW

(Talk delivered at inauguration of the Astronomical Society)

Dr. M. MAHESWARAN

THE image of an astronomer in the eyes of the public was, until recently, that of a man gazing at the sky through a telescope. This, in fact reflected the state of astronomical observation until the second world war. Man's knowledge of the universe was confined to the information brought to him by optical radiation. It is well known that information is transmitted from one part of the universe to another mainly through electromagnetic radiation. Of the radiation that comes towards the earth, all the frequencies except those in the optical and the radio range are prevented from reaching us by the earth's atmosphere. Thus, those observing the universe from the surface of the earth are restricted to receiving information through two "windows" - the optical and the radio. Unfortunately, until about thirty-five years ago, man had been blind to the existence of the radio window and, even then, it was an accidental discovery by Karl Jansky that made us aware of this window. Once this window was open, it did not take long for radio astronomers to observe some fascinating new objects in the heavens. Radio exploration has also led to the better understanding of the old universe and encouraged the optical astronomer to further his own work. In this article it is my intention to very briefly discuss the structure of the old universe, and use this as the framework to discuss two important aspects of the new universe. Yet, as I write this article, astronomers are sending instruments outside the earth's atmosphere to study even newer universes, like for example the X-ray universe.

The Old Universe

In our construction of the old universe the star serves as the most convenient building block. The sun is a star with a mass of approximately 2×10^{33} gms. It is roughly spherical in shape with a radius of 7×10^{10} cm. The mass and radius of the sun are usually denoted M_0 and R_0 respectively. The radiation L_0 emitted from the sun is approximately 4×10^{33} ergs/sec. The masses of stars vary from $\frac{1}{10}$ M_0 to $100M_0$ and their radii vary from $\frac{1}{10}$ R_0, in the case of dwarfs to $1000R_0$ in the case of giants. The luminosities may take any value between $1/2000$ L_0 to $300{,}000$ L_0. Normal stars contain mainly hydrogen, helium which make up about 98 or 99% of the mass. of the star, with a smattering of other elements. The energy generation in a star is the result of the conversion of hydrogen to helium in the central regions of stars, where the temperature would be of the order of a million degrees Kelvin. Stars are believed to be formed through the gravitational collapse of gas clouds. During their initial stages they go through a fully convective phase and subsequently they reach the 'initial main sequence stage.' This nomenclature refers to the Hertzsprung-Russel diagram in astronomy where the luminosity of a star is plotted against its surface temperature. For a group of stars of the same age, it is found that majority of the stars fall along a line, which is almost straight, called the main sequence. Main sequence stars fall into two broad categories, one characterised by the stars on the upper part of the main sequence, called upper main sequence stars, and the other by the stars on the lower part of the main sequence, called the lower main sequence stars. The former are larger and have higher surface temperatures. At the main sequence stage of a star conversion of hydrogen to helium takes place through the radiation of energy away from the star. This evolution takes place on the time scale of 10^9 years. The upper main sequence stars evolve into red gaint stars and the lower main sequence stars into the white dwarf stars. At various stages of the evolution stars become 'variable stars' where pulsation takes place with an accompanying periodic variation in the light emitted.

A galaxy is the largest single unit in the universe. Normal galaxies are each a collection of about 10^{11} or 10^{12} stars. The light that comes from a galaxy is mainly the intergrated emission from the stars. When seen edge-on a galaxy is disc shaped with a bulge in the centre. The shapes of galaxies vary from almost spherical through a variety of elliptical forms to flattened spiral arms of stars and gas clouds. Apart from stars, galaxies contain interstellar gas and dust. The appearance of a dark band on the limb of a galaxy seen edge on, is a result of interstellar matter. The radius of the disc of a galaxy is of the order of 10^4 or 10^5 light years. The separation of stars in a galaxy is thought to be of the order of 1 to 10 light years, and the distances between galaxies are of the order of 10^6 light years.

The old universe may be regarded as the collection of all the galaxies we could see, and their contents. There are some types of visible celestial objects which have not been mentioned. These are only incidental when considering the overall structure of the universe. Firstly, there are the planets, which revolve round the sun in orbits whose radii are few times the radius of the sun. These are many stars in the sky whose radii are larger than the radii of the orbits of planets. It is likely that many stars have planetary systems. Comets and meteors are other objects that roam the neighbourhood of the sun. On a galactic scale the planets and comets are only appendages of the sun.

One of the more interesting sights in the universe is that of a nebula. Nebulae are gas clouds and have been found to exist both within the galaxy, in interstellar space, and in extra-galactic space. A planetary nebula which appears as a beautiful ring or halo in the sky is believed to be gas expanding after a supernova explosion. Theory has it that lower main sequence stars like the sun, evolve into white dwarf stars, which suffer further contraction into highly dense objects and then explode to appear as brilliant spectacles in the sky called novae or supernovae.

When we come to cosmology we find ourselves with a choice of one of two theories. The evolutionary theory takes the view that the structure of the universe is undergoing significant change through time.

On the contrary, the steady state theory assumes that the universe retains the same structure through space and time. However, both theories incorporate one of the most remarkable discoveries in Astronomy, the observation that the galaxies are all moving away from each other. It has also been found that the velocity of recession of any galaxy is directly proportional to its distance from us; the further a galaxy is from us the faster is it moving away from us. This is known as Hubble's law. Hubble's law gives us a limit to the observable universe. The furthest objects we could observe would be those which travel with almost the velocity of light.

The New Universe

Since Jansky's discovery, systematic radio exploration of the sky has revealed many interesting new phenomena in the universe. Well over 10,000 radio sources have been listed. However, only a hundred or so of these are interesting. Majority of these have been identified with optical objects. Upto 1966, 43 radio Galaxies had been discovered, which emit upto 10^6 times the power of our own galaxy. About a dozen were blue stellar objects and about ten were supernova remnants in our galaxy. The most startling discovery in Radio Astronomy was made in late 1967 when a group in Cambridge discovered pulsating radio sources with a period of pulsation of the order of a second and maintaining an exact period, unchanged upto six or seven places of decimals. These pulsars, as they are called now, are one of the two most important objects of the new universe. In this section we shall confine our attention to these two important items, viz. the Quasi Stellar objects and the Pulsars. Only passing references will be made to the other types.

The Radio Galaxies as stated above, are powerful radio emitters. The amount of energy in this radio emission is of the order of 10^{61} ergs, which is equivalent to the rest mass energy of 5×10^5 suns. When compared to the total mass of a galaxy which is of the order of 10^{11} suns, it is quite a large amount to account for. From the nature of the signals received, e.g. polarization, it is now believed that the energy is emitted through the Synchrotron process; the original sources being explosions in the centres of the galaxies.

The radio objects called the Quasi Stellar obejcts (QSO) have turned out to be more puzzling. They have a variable radio signal. From the period of variation, it has been estimated that they are several thousand times smaller than an average galaxy. If, they were galaxies in distant space, the brightness of each must be at least a hundred times that of an average galaxy. If they are local, ie. within our galaxy they would have to be supermassive stars, the like of which has not been known before. First let us consider the nature of their observational properties. These are: (*i*) They emit very powerful radio signals (*ii*) they are associated with bright bluish objects, which also give intense ultra violet radiation and, (*iii*) their spectral lines have red shifts First let us consider the last aspect - that of the red shifts. Red shift is the term commonly used for the displacement of spectral lines towards regions of lower frequency. In the context of Q. S. O.'s there are three possible explanations for the red shifts: (*a*) These could be due to the Cosmological Doppler shifts. By Hubble's law the further the object from us the larger its red-shift. (*b*) The possibility that the red-shifts are due to local Doppler shifts has been ruled out. If the QSO's are local phenomena, ie. if they occur within the galaxy, there is no reason why all of them should exhibit red-shifts. Since we do not occupy a special place in our Galaxy we should see at least a few with blue shifts, which correspond to objects moving towards us. (*c*) Apart from the Doppler effect another cause for red shift is Gravitation. It can be shown that radiation emitted from a massive body is red shifted due to gravitational effects. One of the theories proposed to explain the QSO's used this result. However, this theory requires the QSO's to have mass of the order of 100 times the mass of the sun. The theory has been questioned on the basis that such bodies must essentially be unstable. Thus, majority of the astronomers take the view that the red shift in QSO's is due to the cosmological Doppler effect. If, indeed, this is true, we must be looking at very distant objects. The signals we now receive from them would have left them very early in the history of the universe; roughly 8000 million years ago. The mechanism of energy release is also not yet settled. One of the more popular theories due to Gresnstein and Schmidt suggests that it is due to the synchrotron emission from ionised gas expanding through a magnetic field, after an explosion. Hoyle and Fowler, using the gravitational red shift idea, take the energy to be release due to gravitational collapse of a single object of about 10^8 solar masses. Gold, Ulam and Woltjer have suggested that it could be due to a chain reaction of collisions and collapse within a star system. Mcrea has proposed that it could be due to periodic explosions of stars in a young galaxy. Alfven has invoked the interaction between matter and anti-matter for the energy release. Lynden-Bell suggests that the energy has been released through the catastrophic collapse of the centres of galaxies, leaving the galaxies with 'black - holes' as their nuclei. Thus, it is seen that phenomena of the QSO has evoked so many diverse explanations, and the problem has not been resolved.

Another exciting phenomenon of the new universe was discovered only a couple of years ago. In November, 1967, Hewish's group in Cambridge discovered four points in the sky from which they received peculiar signals. These were sharp signals with a regular period of the order of a second and keeping time correct to about the seventh place of decimal. The pulses were of the order of $\frac{1}{10}$ second long, and varied from one to another. The signal strength was very variable and sometimes not observable. It was discovered that the period of one of the objects was $\frac{1}{4}$ second. Initially, the exceptionally regular nature of the signals led people to think that these came from intelligent beings elsewhere in the universe. However, the random variation of the signals themselves ruled out this possibility.

At first the nature of these pulsars were a mystery. The clock-like regularity had to be controlled by one of three mechanisms. viz. (i) oscillation (ii) revolution, as in the case of binaries, and (iii) rotation. The nature of the signals indicated that the object must be a small star, like the white dwarf or a neutron star. It is remarkable that the neutron star was an object whose possible existence was predicted on the basis of theoretical calculations and it was suggested that even if such stars existed they could not be observed. The possibility that the period of pulsars corresponded to some oscillating source was ruled out on the grounds that any star with such an oscillation period would be unstable. The binary system approach failed due to the fact that two neutron stars revolving around each other would be required to explain the pulsar periods. It has been estimated that the probability of finding a neutron star in space is very low. Hence, the probability of finding a binary of neutron stars would be almost zero. Thus, the only alternative left was a rotating white dwarf or neutron star; the periodically being characteristic of rotation. The choice between the white dwarf and the neutron star was resolved when some Australian Radio Astronomers discovered a pulsar with a period of 89 milliseconds. No white dwarf star could rotate so fast, for, the centrifugal force would have been too large for equilibrium. Further confirmation came when Radio Astronomers in Arecibe, Puerto, Rico, discovered a pulsar in the Crab Nebula with a period of only 31 ms, the shortest known so far. The known periods of pulsars, i.e. from 31 ms to 4 s, suggest not a wide range of models, but a reasonable range of rotation periods, A further discovery made was that the periodicity of the Crab Nebula pulsar was increasing at the rate of 1 part in 2400 per year. All pulsars showed a very small increase in periodically with time. A recent observation has shown that the pulsar in the Crab Nebula is associated with an optical source with the same period.

Let us now look at how pulsars might be formed. In a normal star the enormous gravitational force is balanced partly by material pressure and partly by the pressure due to radiation coming out. When the star uses up its nuclear power, the radiation pressure fails and the gravitational pressure dominates. This leads to a contraction of the star. The atoms condense in to tightly packed nuclei with electrons floating through the whole mass. The star could reach a stage with a density of about 100,000 times that of the sun. This type of star gives out visible light and is called a white dwarf star. A further stage of collapse comes catastrophically and the star becomes a neutron star, consisting mainly of neutrons with a few photons and electrons floating around.

The density increases again by a factor of 10^9. Taking a mass equal to that of the sun we would find that the radius of a white dwarf of the order of 10^4 kilometers and that of neutron star is only 15 km. The catastrophic evolution from a white dwarf to a neutron star is seen as a nova or supernova.

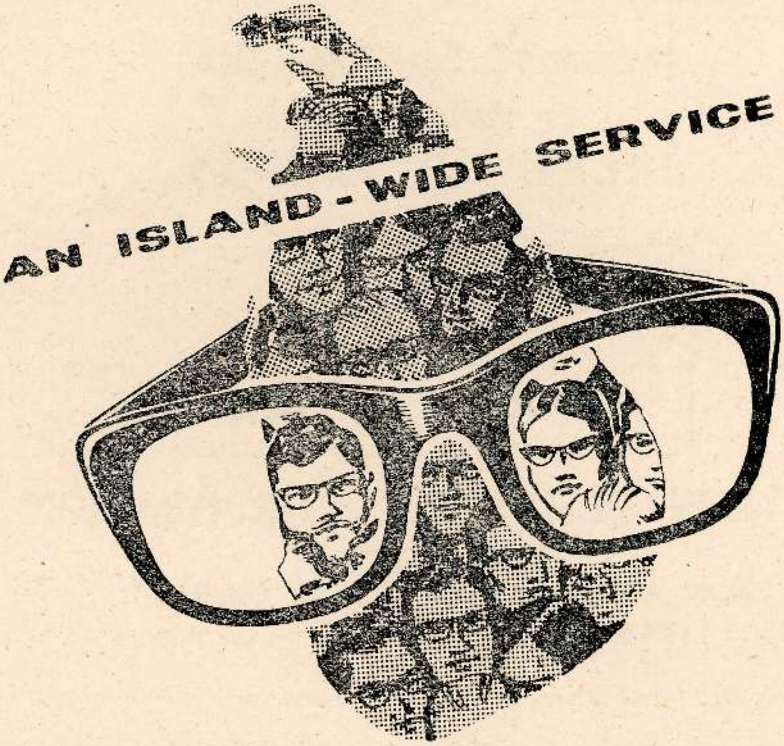
The pulsar is believed to transmit its signals as a result of its magnetic field rotating through ionized gas. The model of a pulsar is that of a rapidly rotating neutron-star with a dipole type magnetic field; the magnetic axis being inclined to the rotation axis. The ionized gas is swept around by the magnetic field. At some point on the field the rotation velocity would be almost that of light. e g. In the Crab Nebula pulsar, which is 15 km in radius, the rotation velocity would reach the value, of the velocity of light at a distance of 1500 km. The relative motion between the gas and the field would give out the pulsar radiation in the form of a beam. The periodic pulses are obtained through the beam coinciding with the line of sight. In some cases, e.g. Crab nebula pulsar, it is believed that two diametrically opposite beams reach us, thus giving two pulses for each rotation of the pulsar, The study of pulsars has also served to bring out information about the insterstellar medium. This medium was used to obtain the distances of pulsars. All pulsars lie within our galaxy and most of these lie in or near the local spiral arm of the milky way. The existence of electrons in interstellar space had been already known. However, pulsar measurements have helped to fix the density at 0.1 electron/cm^2. Further, these observations have also helped to show the existence of irregular structure in the ionized gas in the interstellar medium, so necessary for star formation by gravitational collapse of this gas.

Thus we see that the investigation of the 'new universe' in addition to showing up some fascinating objects has also helped understand the 'old universe' better. With the ever advancing techniques of observation there is no doubt that we shall soon be discovering even newer universes.

NEUTRON STARS....

(Continued from page 15)

the ultimate contraction that may crush our presently expanding universe in another 70 billion years or so. Our universe seems to have exploded to create this space and time and we are forever trapped within its gravitational radius. No light can ever escape from the universe. Man need never collapse with a star - unless some particularly fanatical observational astronomer of the future were to decide to jump into a black hole in his personal pursuit of knowledge! However man cannot avoid collapsing with the entire universe, if he still exists 70 billion years hence. He may then discover whether the entire universe gets crushed into a singularity or whether it aviods the singularity and 'wormholes' through space and time to re emerge explosively somewhere else!


AN ISLAND-WIDE SERVICE

AN ELECTRONIC BRAIN?

V. A. Samaranayake

This is an era where computers are taken for granted. Yet many people believe that there is an intrinsic difference between the activities of a computer and that of the human brain. A similar attitude was taken in the early nineteenth century, when it was widely held that synthesis of organic matter from inorganic materials is an impossibility because the former was believed to possess an essential *vital* force which cannot be artificially produced. It is a continuation of this argument that now rages over the attempts to synthesyse a living cell from non-living materials. But will the "vitalists" be defeated once more and will it be demonstrated with certainity that it is possible to duplicate the human brain with electronic hardware?

It is quite clear that the modern computer and the human brain, though having many things in common, differ basically, both in their functonal as well as structural aspects. A brief glimpse at few of these differences will give the reader some idea of the great disparity between the two entities.

One of the most outstanding features of the human brain is the great *redundancy* in its operations and its structure. Some parts of the brain can be removed without imparing the brain functions. It is also established with certainty, that if necessary, nerve centres can loose their original specialisation and learn to perform new functions. Parts of the brain can take over functions of another part in the case of damage to the latter. In comparison, the computers have very little if not zero redundancy. A failuer or a malfunction in even a seemingly insignificant element would result in a breakdown or malfunction of the whole system. This is especially so if the malfunction is in the memory unit, in which case the computer will not function at all. The separate memory unit of the electronic computer is non exsistant in the human brain. In the brain "memory" seems not to be contained in a specified part, but distributed among the nerve cells of the whole brain.

All these points to a system where neurons (brain cells) are not connected up according to a precise predetermined "wiring diagram" as in an electronic computer, but where interneural connections are randomly made, such that there would be no *basic* difference between any two parts of the brain, either in their structures or in their potentialities. Some of these connections may never be used while some others being used frequently, the preference of one set of connections to the other determined (or devoloped?) by the *conditioning* of the individual concerned.

Of course such a totally random system would not allow for the great number of involuntary activities, instincts, etc., that are carried from generation to generation. This indicates that the brain is partly of predetermined and partly of random organisation. As mentioned earlier the predetermined part's job seems to be to equip us with the basic responses to the "problems" we come into contact with in our infancy. Every computer needs a program to solve a given problem. The above mentioned responses are the basic programs the human brain possess at the beginning of its carrier. As the child grows and his environment and the problems he faces become more and more complex, the need for more versatile programs arise. So the child's brain modifies the programs it already has, *and if these are not satisfactory will device new programs*! In other words the child learns. It is believed that the modification and creation of programs is done by the randomly organised part of the brain. As more and more problems come up and more and more new programs are developed, inter neural connections that give satisfactory results would be used more and more frequently, while the others would be unused. According to its experiences, the brain seems to develop its own "circuit diagram"! The cast-iron design of the electronic computer ever achieving this degree of flexiblity and adaptability seems a very remote prospect.

It is evident that not only is the modern computer a far-cry from the human brain in its capacity for Intelligence and creative work, but also treading on the wrong path, as far as achieving this goal is concerned. If we are to build an analogue of the human brain then we must look deeper into the human brain, and understand at least the basic nature of its structure as well as its functions. Only then can we ever hope to duplicate natures most awesome creation.

கணிதத் தத்துவங்கள்

நா. நவரத்தினம்

ஒரு தொகுதி அனுபவங்களின் இயற்கையான ஒழுங்கின்மையிலிருந்து ஏதாவது உணர்வைப் பெற முயலும் விளக்கமேயொரு தத்துவமெனப்படும்.

ஒரு தத்துவமானது அனுபவங்களையும் அவற்றின் பலன்களையும் தெளிவாக்கவும் முறைப்படுத்தவும் பயன்படுத்தப்படுகிறது. இது ஒரு துறையின் தன்மையொன்றுடன் சம்பந்தப்பட்டதொரு கொள்கை விளக்கமாகும். குறிப்பாக, நாம் பலங்காலங்களாகப் பெற்ற கணித அறிவிற்கு, உண்மையான உணர்வு, முறை ஆகியவற்றைத் தந்து அதை ஒரு நல்லுருவாக்க முயற்சிப்பதே கணிதத் தத்துவமாகும்.

தற்காலக் கணிதத்தத்துவங்களில் முக்கியமானவை மூன்றாகும். அவையாவன (1) ரஸ்ஸல், (Russel) வைட்ஹெட், (Whitehead) ஆகியோர் முக்கிய கர்த்தாக்களாகவுள்ள தருக்கவியல் மரபு. (2) புறோவர் (Brouwer) தலைமை தாங்கும் உள்ளுணர்வு மரபு. (3) முக்கியமாக கில்பேர்ட்டால் (Hilbert) உருவாக்கப்பட்ட சம்பிரதாய மரபு ஆகும்.

இந்நாளில், இவற்றைவிட வேறு தத்துவங்களுமுண்டு. அவைகளில் தனியனாகச் சிலவும், மேற்கூறிய மூன்றில் தங்கியுள்ளதாகச் சிலவும் உண்டு. ஆனால் இக்கட்டுரையில் நாம் மேற்படி குறிப்பிட்ட மூன்று முக்கிய தத்துவங்களையே சுருக்கமாக அறிவோம். இதனிலிருந்து பெரும் விளக்கமானது, கணிதத்தின் அடிப்படை, ஆரம்ப உண்மைகளை, அறியும் தற்காலச் சிந்தனைகட்குப் போதுமானதொரு எண்ணத்தை அளிக்கும்.

தருக்கவியற் கொள்கை: இக் கொள்கையின் படி, கணிதம் தருக்கத்தின் ஒரு கிளையென்றும் அது கணிதத்தின் ஆயுதம் என்பதைவிட கணிதத்தின் மூலகர்த்தாவென்பதே பொருத்தமாகும். எல்லாக் கணித உண்மைகளும், தருக்க உண்மைகளாகவும் எல்லாக் கணிதத் தேற்றங்களும் தருக்கத் தேற்றங்களாகவும் உருவாக்கப்படுகின்றன. இதனால் கணிதத்திற்கும் தருக்கத்திற்குமிடையிலான வித்தியாசம் ஆகச் செய்முறை வசதியொன்று மாத்திரம்தான்.

கொள்கைகளும், சிந்தனைகளும் ஆகக்கொண்ட விஞ்ஞானமாகத் தருக்கத்தை உருவாக்கத் தொடங்கியவர் 1666 இல் வாழ்ந்த லீபினிட்ஸ் (Leibnitz) ஆவார். பின் டெடிகைன்ட் (Dedekind) (1880), ஃபிறெஜ் (Frege) (1884) ஆகியவர்கள் கணித உண்மைகளைத் தருக்க உண்மைகளாகச் சுருக்கித் தந்தனர். பியானோ (Peano) (1889) என்பவரால் கணிதத் தேற்றங்கள் தருக்கச் சின்னங்களில் குறிப்பிடப்பட்டன. இவர்களெல்லோராலும் முன்னேற்றப்பட்ட தருக்கவியல் மரபானது, வைட்ஹெட், ரஸ்ஸல் எனுமிருவரால் உருவாக்கப்பட்ட "பிரின்சிபியா மதமெடிக்கா" (PRINCIPIA MATHEMATICIA) எனுஞ்சிறப்பான நூலால் ஒரு நிலையான உருவையடைந்தது. இப்பெருஞ் சிறப்பான செயலால், எல்லாக் கணிதமும் தருக்கத்திற்குச் சுருக்கப்பட்டது. இது, விற்கென்ஸ்டீன் (1922) சுவிஸ்டிக் (1924) ராம்சே (1926) லோங்போர்ட் (1927) கார்ன்நாப் (1931) ஆகியோரால் மேலும் மெருகூட்டப்பட்டது.

"பிரின்சிபியா மதமெடிக்கா" பழைய சிந்தனைகள், எடுப்புகள் ஆகியவற்றை வரைவிலக்கணப்படுத்தாத உறுப்புக்கள், கொள்கைகள், எனக் கொண்டு ஆரம்பிக்கிறது. இப்பழைய சிந்தனைகள், எடுப்புகள் வகைக்குறிப்பிற்கு, உள்ளார்க்கப்படாதவை யெனவும் ஆனால் தருக்க உள்ளுணர்வு உண்மைகட்கு உட்படுத்தப்பட்டனவென்றும் அது கூறுகிறது. சுருக்கமாகக் கூறின் "பிரின்சிபியா மதமெடிக்கா" வில் பழைய உண்மைகளை நிரூபிக்க ஒரு முயற்சியும் எடுபடவில்லை. அதன் முக்கியநோக்கமானது, பழைய எண்ணங்கள், எடுப்புகளிலிருந்து, கணித உண்மைகளையும், தேற்றங்களையும் பெற்று எடுப்பு நுண் கணிதத்தால் இயற்கையெண் தொகுதியை உருவாக்கிப் பின், எல்லா கணிதக்கிளைகளையும் அதனிலிருந்து பெறுவதாகும். இவ்வுருவாக்கத்தில் ஒரு தொடை கேவல எடுகோள்களால் (Abstract Propositions) பெறப்படும் தனித்துவமற்றதாக இயற்கையெண்கள் கொள்ளப்படாது, அவை தனித்துவ அர்த்தங்களைப் பெறுகின்றன.

தொடைக் கொள்கையின் முரன்பாடுகளைத் தவிர்க்க, "பிரின்சிபியா மதமெடிக்கா" ஒரு

வகைக்கொள்கையையும் (Theory of Types) தருகிறது, இக்கொள்கை மூலக மட்டங்களின் பரம்பரையை உண்டாக்குகிறது. இதன்படி தொடக்க மூலங்கள் வகை 0 ஐ உண்டாக்குகின்றன; இது பின் வகை 1 ஐ உருவாக்குகிறது; இப்படியே மற்றவகைகளும் உண்டாகுகின்றன. இதனால் எந்தவகையிலுமுள்ள மூலகங்கள் ஒரே வகையைச் சேர்ந்தவையென்ற விதியை அறியலாம். இவ்விதியின் ஒத்துழைப்பு, வரையறுக்கப்படாத வரைவிலக்கணங்களை முன்வைத்து, அதனால் தொடைக்கொள்கையின் முரண்பாடுகளைத் தவிர்க்கிறது. "பிரின்சிபியா மதமெடிக்கா" வில் தரப்பட்ட படி பரம்பரைகள் பிரிவு பிரிவான வகைக்கொள்கைகளை உருவாக்குவதற்காகத் தோற்றுகின்றன. இங்கு பகுப்பு உருவாகுதற்குத் தேவையான வரையறுக்கப்படுத்தாத வரைவுகளைப் பெறுவதற்குக் குறைப்பு வெளிப்படையுண்மையொன்று (Reuceion axiom) புகுத்த வேண்டியிருந்தது. இவ்வெளிப்படையுண்மையின், பழைமையற்றதும் ஏதேச்சையானதுமான தன்மை, பெரிய விவாதத்திற்குரியதாய் அமைந்ததால் இவ்வுண்மையைத் தவிர்ப்பதன் மூலமே, தருக்கவியற் கணிதம் தூய்மை பெறும். எப்படியெனினும் அபிப்பிராயத் தன்மையே தருக்கக் கொள்கையை உருவாக்கின்றது. தருக்கத்தின் தொகுதி உருவாக்கம் கணித எண்ணங்களைத் தன்னகத்தே கொண்டுள்ளதே யென்ற பிரச்சனையும் எழுகிறது.

உள்ளுணர்வு கொள்கை: உள்ளுணர்வாற் பெற்ற இயற்கையெண் தொடரிலிருந்து. உறுதியான வழிகளில் உருவாக்கப்பட்டதே கணிதமென்பது உள்ளுணர்வியலாளரின் கொள்கையாகும். இதிலிருந்து, கணிதத்தின் அடிப்படையாக்கம், முன்—பின் என்ற காலச் சார்பான தன்மையுடன் சம்பந்தமான ஆரம்ப உள்ளுணர்விலுள்ளதென்பது புலனாகும். இவ்வுணர்வினால், இயற்கையெண் தொகுதி பெறப்படும். பின் இவ்வியற்கையெண் தொகுதியிலிருந்து, எந்தவொரு கணித நோக்கத்தையும் தூய்மையான, ஆக்க பூர்வமான வழியில் முடிவுள்ள சில எடுப்புகளிலும் செய்கைகளிலும் உண்டாக்க முடியும்.

உள்ளுணர்வு மரபு, 1908 இல் டச்சுக் கணித வல்லுனர் L.E.J. புரூவரால் உருவாக்கப்பட்டது. எனினும் முன்னமே குரேநெக்கர் (1880) பொன்காறே ஆகியவர்களால் சில உள்ளுணர்வு எண்ணங்கள் உருவாக்கப்பட்டிருந்தன. படிப்படியாக இம் மரபு பெரிதாகி, தற்காலத்தில் சில சிறந்த கணித வல்லுனர்களையும் உருவாக்கியிருக்கிறது.

உள்ளுணர்வுப் பள்ளியின் சில பலாபலன்கள் புரட்சித் தன்மை குறைந்தவையாகும். அதனால், கணிதத் தோற்ற உண்மையை நோக்கும் உறுதியான வழிகளின் மேலிருக்கும் தூண்டுதல், பல கணித வல்லுனரால் பங்கு கொள்ளப்படவில்லை. உள்ளுணர்வியலாளருக்கு இருப்புண்மை முடிவுள்ளசெய்கைகளில் நிறுவப்படவேண்டியதொரு கணித உண்மை ஆகும். மேலும் அவர்க்கு இவ்வுண்மையின் இருப்பின்மை எடுகோளை எதிர்மறுக்கிறதென்று நிறுவல் போதியதன்று.* இதனால் தற்காலக் கணிதத்திலுள்ள பலதோற்ற நிறுவல்கள் இவர்களால் ஏற்றுக்கொள்ளப்படவில்லை. ஆக்க பூர்வமான வழிகளின்மேல், உள்ளுணர்வாளருக்கிருக்கும் முக்கிய நோக்கம், தொடைக்கொள்கையிலுமுள்ளது. இவர்கள் ஒரு தொடையை 'ரெடிமேட்' சேகரிப்பாக எண்ணமாட்டார்கள். ஆனால், மூலங்களால் படிப்படியாக உருவாக்கப்பட்டதே தொடை என்பது இவர்களின் சிந்தனையாகும். தொடையைப்பற்றிய இக்கொள்கை எல்லாத் தொடையின் தொடை தோற்றுவதை எதிர் மறுக்கும். இவர்களின் முடிவுள்ள உருவாக்கத் திட்டத்தில், ஒரு குறிப்பிட்ட இன்னொரு பலனும் உண்டு. அது, இரு பெறுமானத் தருக்கத்தில் ஏற்றுக்கொள்ளப்பட்ட நடுப்புற நீக்கு விதியை எதிர் மறுப்பதாகும். உள்ளுணர்வியற் கொள்கையின் படி நடுப்புற நீக்குவிதி, முடிவுள்ள தொடைக்கு ஏற்றுக்கொள்ளக் கூடியது; ஆனால் முடிவற்ற தொடைக்கு ஏற்றுக்கொள்ளக் கூடியதல்ல என்பதாகும்.

மனிதன் வளர்ச்சிக் காலத்தில் அவன் முடிவுள்ள தொடைகளுடன் சம்பந்தப்பட்டிருந்த போது தருக்கவிதிகள் புகுத்தப்பட்டன. ஆனால் இவ்விதிகளை மீண்டும் முடிவற்ற தொடையில் பிரயோகிக்கும் பொழுது பிழையேற்படுகிறது. ஆகவே உள்ளுணர்வியலாளர், உள்ளுணர்வுச் சின்னத்தருக்கத்தை உருவாக்கினர்,

உள்ளுணர்வியலாளரின் தடைகளுக்கமைய எவ்வளவு கணிதம் உண்டாக்கலாமென்ற வினு

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* முரண்காட்டி மறுக்கும் நிறுவல் முறை, இருப்புண்மையை நிறுவப் போதியதன்று. ஆக்க முறையால் இருப்புண்மை நிறுவப்பட வேண்டும்.

இங்கு எழுகிறது எல்லாக் கணிதமும் திருப்பியுருவாக்கப்படின், கணித உருவாக்கத்திலுள்ள தற்போதைய பிரச்சனைகள் யாவும் சுலபமாகத் தீர்ந்துபோகும். இப்பொழுது தொடர்ச்சிக் கொள்கை, தொடைக்கொள்கை உள்படக் கணிதத்தின் பெரும் பகுதி திருப்பியுருவாக்கப்பட்டு விட்டது. இற்றை வரை உள்ளுணர்வுக் கணிதம் சாஸ்திரீய கணிதத்தை விட வலுக்குறைந்ததாகவே இருக்கிறது. மேலும், இது விருத்தியாவதற்கு மிகச் சிக்கலாகவுள்ளது. வேறுவகைகளில், இவ்வுள்ளுணர்வு வழியில் சுலபமாச் செயலாற்ற முடியுமெனின், இந்நிலை நெடுகிலுமிருக்க வேண்டிய அவசியமில்லை உள்ளுணர்வுக்கொள்கை வழிகட்கு ஏராளமான எதிர்ப்புகளிருந்தும், இதன் ஆக்கம் எதிர்மறுப்புகளை நோக்காததால் தப்பித்துக்கொள்கிறது.

சம்பிரதாய மரபு: சம்பிரதாயக் கொள்கையில், கணிதம் சம்பிரதாயச் சினனத் தொகுதியைக் கொண்டதாகும். உண்மையில் கணிதமானது அம்மாதிரியான கேவல உருவாக்கத்தாலான சேகரிப்பாகும், இதில் வார்த்தைகள் சின்னங்களாகவும், எடுப்புக்கள் அச்சின்னங்களைக் கொண்ட சமன்பாடுகளாகவுமிருக்கும். இதன் படி, கணிதத்தின் அடிப்படையானது, தர்க்கத்தில் தங்கியிருக்குமொன்றல்ல; ஆனுல் அது முந்திய தருக்கவியல் அடையாளங்கள் அல்லது சின்னங்கள் அவற்றுடன் உள்ள செய்கைகள் கொண்ட சேகரிப்பாகும், ஆகவே, கணிதம் உறுதியானதொரு அடக்கத்தைக் கொள்ளாததெனவும், ஆதர்ச சின்ன மூலங்களை மாத்திரம் கொண்டதெனவும் புலப்படும். இதனுல் கணிதத்தின் பல்வேறு கிளைகளின் ஆக்கபூர்வமான உருவாக்கம், சம்பிரதாயவியலில் முக்கியமானதும் தேவையானதுமான செயலாகும். இத்தகைய உறுதியான உருவாக்கமின்றி அம்முழுக் கல்வியும் உணர்வற்றதாகிவிடும்.

சம்பிரதாய மரபானது, டேவிட் ஹில்பேர்ட் (David Hilbert) என்பவரால் உருவாக்கப்பட்டது. 1899ல் வெளியிடப்பட்ட அவரது புத்தகத்தில் உணர்வுள்ள கணிதமுறைகளை இக்கால சம்பிரதாய வெளிப்படையுண்மை முறைக்கு மாற்றும் வழியைக்குறிப்பிட்டார். 1904 இல் ஹில்பேர்ட் இது பற்றிப் பேசியிருந்த போதும், 1920 இல் தான் சம்பிரதாயக் கொள்கையின் உருவாக்கம் நன்கு முயற்சிக்கப்பட்டது. சாஸ்தரீய கணிதத்தைக் காப்பாற்றும் ஹில்பேர்ட்டின் இம் முயற்சியின் வெற்றி தோல்வி, இசைவுப்பிரச்சனையிலே (Problem of Consistency) தங்கியுள்ளதாகும். பழைய இசைவு நிறுவல்கள் ஒரு கணிதத்துறையிலிருந்து மறு கணிதத்துறைக்கு மாற்றம் வகைக்குறிப்பிலும் மாதிரிகளிலுமே தங்கியுள்ளன. ஆகவே ஹில்பேர்ட் இப்பிரச்சனைக்கு வழிகாண ஒரு புதிய அணுகலை அடையத்துணிந்தார். அவருடன் பேர்நேய்ஸ் என்பவரும் சேர்ந்து 1934 - 39 இல் வெளியிட்ட இரு புத்தகங்களில் அப்புதியவழிகள் கிடைக்கப்பெற்றன. சில எதிர்பாராத கஷ்டங்களினுல் நிறுவற் கொள்கையையை பூரணப்படுத்துவது முடியாததாகிவிட்டது. சில ஆரம்பத் தொகுதிகட்கு ஹில்பேர்ட்டின் இசைவு நிறுவல்கள் செயலுற்றன. ஆனுல் சில தொகுதிகள் இணங்க முடியாததாகிவிட்டன.

1931 இல் அதாவது ஹில்பேர்ட் தனது புத்தகத்தை வெளியிடுவதற்கு முன்பே, ஹேடல் (Godel) என்பவர் இசைவு நிறுவத் திட்டத்தின் தோல்வியை நிறுவினுர். "சிறப்பான உருவாக்கத்திலமைந்த உய்த்தறிவு தொகுதியைக் கொண்டு, அத்தொகுதியிலுள்ள வழிகளால், அத்தொகுதியின் இசைவையே நிறுவுவது" இயலாத தொன்றென ஹேடல் காட்டினுர். இதனுல் இசைவு நிறுவற் திட்டம் வெற்றி பெறவில்லை.

எனினும் மேற்கூறிய மூன்று தத்துவ மரபுகளில், தற்காலக் கணிதவியலாளர் பலர் பின்பற்றுவது சம்பிரதாய மரபேயாகும். தருக்கவியல் மரபு பெரும்பாலும் பிரிட்டிஷ் கணிதவிவலாளரால்தான் பின்பற்றப்படுகிறது.

* * *

LASERS

K. R. S. S. Kekulawala.

WITH the advent of the Laser man's control of light has reached an entirely new level. It has been possible to attain precise control of the ganeration of light waves. The outstanding characteristics of laser light is that waves unlike the waves from ordinary light sources are co-ordinated in space and time. It is remarkably intense, directional and chromatically pure.

The most important limitation of ordinary light is their inherent low brightness. In fact they can't emit more energy than a perfect radiator. The theoritical output of a perfect blackbody is given by the famous Planck's Law.

In a laser the approach is to synchronize a large no: of atoms, so that they can work together to produce a powerful coherent wave. This has been made possible by the Maser principle discovered by Towne's. The Laser, which has its birth from the Maser, stands for 'Light Amplification by stimulated Emission of Radiation'.

Stimulated emission which is the basis of Laser action is the reverse of the process in which electromagnetic photons are absorbed by an atomic system. During the period in which an atom is still excited it can be stimulated to emit photons, if it is struck by an outside photon having precisely the energy of the one that wouid otherwise be emitted spontaneously. As a result the incoming photon is augmented by the one given up by the excited atom. This wave falls in phase with the wave that triggered its phase. Most lasers consist of a colomn of active material that has a partly reflecting mirror at one end and a fully reflecting mirror at the other. The waves generated are thus reflected back and forth by the mirrors. The colomn whose length is a whole number of wave lengths acts as a cavity resonator, and a beam of monochromatic, coherent light rapidly builds in intensity as one atom after another is stimulated to emit photons with the same energy and direction. Consequently the first requirement for laser action must be that the energy levels concerned are not in thermal equilibrium and that the upper of the two levels be more populated than the lower. This is known as population inversion.

Until the first laser was made by Maiman in 1961, the human eye has only observed spontaneous emission. Constructive and destructive interference of the waves results in some mean amplitude being observed for the resultant emission. Consider an idealized 2-level atom capable of emitting frequeny. ν If the waves are randomly phased; the compex amplitude of a particular wave can be written as $\Phi_k = a_k e^{i\delta_R}$; δ_R = phase angle. For an assembly of n atoms, resulting amplitude;

$$\Phi = \sum_1^n \Phi_k$$

Since $\phi_1 = a_1 (\cos \delta + i \operatorname{Sin} \delta_1)$;

$$\Phi = A (\cos \triangle + i \operatorname{Sin} \triangle) \text{ where}$$

$$A \cos \triangle = \sum_1^n a_k \cos \delta_k$$

$$A \sin \triangle = \sum a_k \sin \delta_k$$

By squaring and adding we get.

$$A^2 = \sum_1^n a_k^2 (\operatorname{Sin}^2 \delta_k + \operatorname{Cos}^2 \delta_k)$$
$$+ \sum (a_k \cos \delta_k a_j \operatorname{Cos} \delta_j + a_k \operatorname{Sin} \delta_k a_j \operatorname{Sin} \delta_j)$$

The second term will vanish, since there is no correlation in the behaviour of different waves. Then the intensity is given by

$$I \propto A^2 = \sum_1^n a_k^2$$

ie $I \propto n \bar{a}^2$; $\bar{a}$ is the mean amplitude of the disturbances. The resultant intensity is proportional to No: of excited atoms.

If in someway, the atoms are made to emit waves in phase; the case would be;

$$\Phi = A \cos \wedge + i \operatorname{Sin} \wedge$$

$$A \cos \wedge = \operatorname{Cos} \delta \sum_1^n a_k$$

$$A \operatorname{Sin} \wedge = \operatorname{Sin} \delta \sum_1^n a_k$$

$$A^2 = n^2 \bar{a}^2$$

The resultant intensity is proportional to the square of the number of excited atoms.

The Laser is, to some extent at least the result of turning this second possibility into a reality.

The physical structure of the apparatus needed to create a suitable environment for stimulated emssion to occur to a sufficient extent is such that the light is emitted into a small solid angle; unlike spontaneons emission which is emitted in all directions This idea together with phase, explains the great intensity of the emitted laser beam.

The amplification coeffieient can be understood by considering the amplifications at the centre of a Dopper broadened line, which is given by:

$$k_0 = K \frac{A_{21} \lambda^4}{\triangle\lambda_D} (N_2 - \frac{g_2}{g_1} N_1)$$ ....(due to Maobel+Zemansky)

where A_{21} = transition probability from level 2 to 1

λ = Wave Length

$\triangle\lambda$ = Doppler width

g_1; $^D g_2$ = Statistical weight of the levels involved.

If $N_2 < \frac{g_2}{g_1} N_1$; k_0 is an absorption coefficient

and if $N_2 > \frac{g_2}{g_1} N_1$; k_0 is an amplification cofficient, if there is population inversion.

Here k_0 Corresponds to Laser gain per unit length of the medium

The Laser is more an oscillator than an amplifier. Analogous to an electronic oscillator, we have the components, a tuned circuit, a feedback system and a power supply. It can be regarded as a noise started oscillator, where the noise is spontaneous emission. This randomly phased light with its finite spread of frequency serves to build up a radiation feild at certain resonant frequencies; which in turn acts as a stimulating feild in thet induced emission process enjoyed by the other exculed atoms.

It was Maiman, who first succeeded in putting these ideas into the practical language. When triply ionized chromium in cystal ruby (Alo) is irradiated at a wave length of about 5500 A he found that chromiurn ions are excited to the $4F_2$ state and then quickly lose, some of their excitation energy through non radiative transitions to a metastable state ^2E. This state slowly decays by spontaneonsly emitting a sharp doublet the components of which are 6943 A and 6929 A. Under very intense excitation the population of this metastable state can become greater than that of the ground-State. This is the condition for negative temperatures and consequently amplification via stimulated emission.

Production of negative absorption was done in late 1961 by using electron excitations. This population inversion in gases led to the discovery of the first gas-laser, the He—Ne laser. In 1962 experimentalists succeeded with a p-n junctions of Ga As, as a Semi-conductor Laser material.

Unlike most scientific discoveries, lasers received immediate public attention. Mankind acquired and succeeded in controlling entirely new sources of light whose radiation is vastly superior in precision and intensity to light obtainable from sources known before. Its remarkable properties opened ways for unprecedented Scientific technical and military applications. The award of the Nobel prize in physics (1964); to three scientists, who opened the new field of quantun electronics by discovering the maser, the ancestor of the Laser itself; shows the rapid recognition of the Scientific and practical significance of Lasers.

NEUTRINO ASTRONOMY

A. L. M. A. Gaffoor

Prof. Frederick Reines, has said " 'Neutrions'- the ashes of the Universe - carry valuable information about events in Sun's centre, the birth of supernovae and the properties of cosmic rays. But because these particles have no mass, neutrino telescopes must be located deep below the Earth's surface".

This worthy scientist while stating its unique scope, also points out its peculiarity, and difficulty. Its unique in that it studies things - the centre of the sun, the birth of supernovae, properties of cosmic rays and why even the birth of the universe itself - that no other method can hope to study. Its peculiar in that "we seek to see the heavens in a manner that does violence to common sense - we go deep underground!"

These neutrinos are produced in

1. Radioactive Beta decay of matter.
2. Nuclear accelerators and other ways such as fission.
3. In the atmosphere by the collision of cosmic rays with a mosphertic atoms.
4. Nuclear fire that is believed to power our sun and other stars.
5. Nuclear reactions occuring when supernovae explode.
6. Interstellar and intergalactic matter by the collision of cosmic rays.
7. Those neutrinos that must have been produced when the first explosion of matter took place to form the universe if it came into being that way!

Of these, 4, 5 and 6 are important to our immediate requirements in astronomy - cosmology to be precise. But it is from the first two that we study the behaviour of the neutrino. We apply the knowledge so gained to study the atmospheric neutrinos which are relatively easy to study.

Some forty years ago the neutrino was only a theoretical particle conceived by Pauli in 1930 to extend the conservation laws of energy and momentum to nuclear domain. It was discovered only in 1956, by Cowen and Reines.

1. Neutrino has no or extremely small mass.
2. It has no charge.

The above properties make its interaction with matter extremely rare. In fact, it is estimated that one kind' of neutrino (There are a few kinds depending on their energy)- a moderate one- can travel in liquid hydrogen for 100 light years before colliding with a hydrogen atom.

3. Once a neutrino is produced it keeps its direction. Nothing except the gross gravitational field of the universe can have any effect on this direction.

4. A neutriou has a definite amount of energy associated with it on production and this energy is conserved.

In nuclear reactions the initial and final energies do not balance ie. there is a loss of energy - a fundamental violation of Physics, the Law of Conservation of Energy.

Briefly consider the reactions that we believe take place in the centre of the sun and which also produce neutrino we can quote:

$H_{+1} + H_{+1} \rightarrow H_{-2} + n$ of energy 0.4. MeV.

$Be_{-7} + e \rightarrow Li_{-7} + n$ of energy 0.9 MeV

$Be_{-8} \rightarrow 2He_{-4} + e+ + n$ of energy 1.4 MeV

If we detect neutrino with energies 0.4, 0.9 and 14 MeV and coming from the direction of the sun then we can be quite certain that our model to power the sun was correct.

At the moment there are only a few Neutrino - Telescopes. They are not worth the name because they are so crude and small in this context, though they occupy hundreds of square yards of underground space, and are thousands of feet below surface.

The techniques can be illustrated by a few specific examples. The most sensitive experiment for the detection of the solar neutrinos is probably that of R. Davies.

Here solar neutrinos will interact with Cl-37 in a large tank of perchloroethylene (C_2 Cl_4). The product Argon (A-37) will be swept out of the tank by a stream of Helium and then collected in a tiny low background counter. His observatory is placed one mile below surface and has a target tank of 100,000 gallons of C_2 Cl_4 : He expects 5 counts/day.

There are two other approaches both of which depend on direct hits. First, proposed by R.Woods, F. Reines and J. Bahcall, depends on the reaction.

$$N + Li_{7} \longrightarrow Be_{7} + e$$

Here slabs of lithium incorporated into a liquid scintillation counter which detects the product electron. They expect about 50 electrons per year.

The second, proposed by R. Kropp and F. Reines see this via the so called scattering reaction.

$$n + e \longrightarrow n + e$$

Its something like our collision problems. The moving n gives energy to the stationary electron. The energy of the neutrino can be calculated from the energy of the struck electron. If we also measure the direction of the struck electron the neutrino's direction could be infered. In the deep mines of S. Africa 1000 gallons of liquid scintillator is viewed by some 70 photomultipliers. This detector is enclosed in 40 tons of paraffin wax to shield it from natural radio activity! They expect about 20 counts/year.

These experiments should lead us to an understanding of what happens in the interior of our energy supplier, the sun and indeed all the stars.

I described ony the case of the sun. The other sources of neutrino also could be studied in a similar manner though details are varied.

Even in the solar telescopes described they are capable of detecting only one out of the three we set out to find. So many other methods still remain to be designed to study the full 'Solar Neutrino Spectrum". Then again there are other neutrino sources with different types of neutrinos for which special devices have to be designed. Also one has to know one from the other of the different types of neutrino and this is no small task.

Point defects in Solids

Dr. K. Tharmalingam

As we know a perfect solid consists of atoms arranged in some regular array. A defect in the crystal structure may arise from atoms missing from their regular sites, called vacancies, or foreign atoms inserted in the crystai structure either substitutionally or interstitially, called impurities.

The p — type and n — type semiconductors are well known examples, of systems, where a defect is purposely introduced. In these systems the interesting physical effects, of the defect, arise from the electronic levels introduced by the impurities and can be seen by measurements of optical properties and of electronic conductivity.

On the other hand the atomistic nature of the defect can be seen in, matter transport like in, diffusion and ionic conductivity measurement. In ionic crystals, like Nacl for example, a missing Na + is equivalent to a hole carrying a negative charge and this can be indentified experimentally by measuring the electrical (ionic) conductivity. In metals like Cu, however, the atomic hole is neutral and can only be identified by diffusion experiments. Both ionic conductivity and diffusion involves the movement of a defect. And for this process to occur the atom, responsible for migration, has to jump through a potentical barrier — a saddle point in fact.

One of the many delights, of the theoretician working in the field of defects, is to calculare the energies needed to form a defect and the energy required for the defect to jump over the potential barrier. Even in the present age of high speed computers, only rough estimates of these energies can be obtained theoretically and amounts to few electron volts. The difficulty of the problem can be seen from the fact that if, for example, we pull out an atom from a solid thus forming a vacancy the atoms sorrounding the hole, and in fact the infinite number of atoms of the lattice, are all displaced from their perfect lattice positions. The main problem is to calculate, knowing the forces, the new equilibrium configuration and hence the energy of the defect lattice. The calculations, though in principle straightforward often suffers from the inaccuracies of the interaction potentials between atoms. It might appear obvious that the interaction potential between two atoms could be derived from the electronic model of the atoms themselves.

The difficulty however is to know whether interaction potentials derived thus are valid in the defect lattice. At the moment, however, semiempirical interaction potentials derived from various experimental data on perfect lattice are used in these calculations.

In conclusion we remark that the results of such calculations, not only gives us estimates of the energies as mentioned earlier, but, also throw some light on the validity of model as well. In fact recent results of calculations of this nature shows that some of the ionic crystals are better represented by the "shell model" as opposed to the well known point in model.

● ● ●

This Journal has been completely passed

by the competent authority.

A WORD FROM

H. GUNAWARDENE

(Vice President, Ceylon Astronomical Association. Council Member International Union of Amateur Astronomers).

IT is indeed a pleasure to note that another issue of SIGMA has been produced by an enthusiastic group of students of the Colombo University. This particular issue is also significant, because it is a combined effort of the Astronomical and Mathematical Societies of the University. Although there is no separate Department for Astronomy as such, some students and senior lecturers are trying to devote some of their spare time towards the subject and are also keen in getting the 13 inch Reflector back into operation. All this is very noteworthy because even as far back as 11 years ago the Needham Commission had recommended the setting up a Department of Astronomy in our University.

The importance of a subject like Astronomy is not apparent on the face of things. But as a subject with ramifications into many other sciences both in the theoritical and practical fields, its importance cannot be disputed. However spare time studies by a handful of students is not good enough for a University. At least some official recognition even within the framework of the Mathematics Department must be found. As Astronomy is mainly a subject for research it would mostly interest post graduate students, scholars and research workers from outside.

Regarding instruments the 13 inch Reflector in the campus (when brought back into working order) would be quite sufficient for a start. Accessory equipment such as plate holders and a photo electric photometer could be bought or built. What is urgently needed is to organise systermatic Astronomical studies within the University, and it is in this direction that we need help from others with experience. Some post graduate students could be trained in the fields of Astronomical instrument maintenance and modern observational techniques. These persons could then help others on how to observe and analyse results. On the strength these theoritical studies may be attempted. I can say here that many countries are willing to help us, if only we ask them. The standard of our science students have always been high, and there is little doubt that given the right opportunity our students would shine in the field of Astronomy too. I wish the University Astronomical Society all success in the furture.

Acknowledgments

THIS page, which appears very much as if it is reserved for acknowledgments;... pause,... think — it is unscientific to jump to conclusions; is, in fact, the page reserved for acknowledgments!

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