MATHEMATICA

ANNUAL JOURNAL
OF THE
CEYLON UNIVERSITY
MATHEMATICAL SOCIETY
1963

Today and Everyday!

Mercantile Credit Limited

Queen Street Colombo 1

KEERTHI CINEMA

KADUGANNAWA

EXHIBITORS OF

QUALITY

MOTION

PICTURES

University Undergraduates

Half rates for batches of 50 and over. Special Shows arranged to suit their convenience.

WILLIAM'S FURNISHING HOUSE

FOR

Excellent Furniture

AND

All other Household Goods

38, COLOMBO STREET

KANDY

T'PHONE **7124** T'Gram : **Williamson KANDY**

Annual Journal of The University Mathematical Society

1962-1963

Edited By :— **Dudley Jayatillake**

VOL. I

CONTENTS

EDITORIAL NOTE

The aim of this publication is foster interest in the field of Mathematics through which chemical progress in many other fields have been made since, as in Physics and Chemistry. This carries articles of ten general type on Maths, Physics and Chemistry. Incidentally this is the only magazine published by the Science Faculty at Peradeniya.

My sincere thanks are due to:

Our Patron Mr. C. R. Kulatillaka, Mr. M. Maheswaran and the other members of the Staff for the invaluable assistance and guidance.

All our contributors for their painstaking work on the articles.

To Messrs. Gamini Meemeduma, Ranjan Fernando, Felix Karunaratne and Raja Seneviratna for the whole hearted co-operation they have rendered.

To all our advertisers who have helped us in spite of difficulties.

Mr. R. L. de Alwis of the University Press for the trouble he had taken in bringing out this inaugural issue.

Euclid.

Our first naive impression of Nature and matter is that of continuity. Be it a perfect metal or a volume of liquid, we invariably conceive it as divisible into infinity, and ever so small a part of it appears to us to possess the same properties as the whole.

David Hilbert.

How can it be that mathematics, being after all a product of human thought independent of experience, is so admirably adapted to the objects of reality ?

Albert Einstein.

There is no roal royal to Geometry.

Archimedes.

THE EDITORIAL

The 'Mathematica' makes its inaugural outing in an attempt to sum up events of Scientific and Technological interest which in the past decade have made tremendous advancements, fundamentally propelled through the principles of Mathematics—adding yet another tribute to the human genius.

As usual in all research for the origin of ideas that have become potent in the civilization of the world we come to the Greeks of old. They were certainly the first great mathematicians and they cultivated the Science assiduously and with wonderful success from Pythagoras to Archimedes—Archimedes had reached a point when modern forms began to appear clearly, for he had already worked in his spirit of infinitesimal calculus—Newton's contributions to those branches of physical science that were studied in the seventeenth century mark a peak of Achievement. At the same time it disclosed the fruitful prospects of the future advances of science. His own examples were so commanding, and his own explorations were of such range that for about a century no investigation passed the limits of the Newtonian framework. In the eighteenth century, Mathematics took tremendous steps forward in development. Algebra was extended and systematised; trigonometry was generalised to form a branch of mathematical analysis; calculus was developed and applied to problems in geometry, mechanics and physics. A general theory of functions was established. Theories of equations and infinite series were propounded. The Calculus of variations was founded and the doctrine of probability was developed. The principle of analytical geometry followed more general formulation and a beginning was made with descriptive geometry. Mechanics was enriched with several new generalisations, namely the Principle of Conservation of Vis Viva, D'Alembert's Principle and the Principle of least action. Mathematical analysis was increasingly applied to mechanical problems; and systematised.

In systematising mechanical problems new frontiers have been opened in various fields. One of the foremost developments is the invention of computers, geared to solve many a intricate problem which would have otherwise been difficult. Russia and U.S.A. have taken great steps forward in the conquest of outer space and have gathered a vast quantity of data that will help them to spearhead the conquest of the .heavens in an endeavour to satisfy man's curiosity. It may not be long before we may hear that an astronaut had landed on the moon. The development of Atomic Energy has brought about in its wake a feeling of fear precipitated by the ever increasing possibility of self extermination by a thermonuclear catastrophe and yet there is relief that the energy of the sun is being harnessed for the greater benifit of mankind. Even at this stage Atomic Energy is used in nuclear power reactors in producing electricity which is used in many industries. There are ships and aeroplanes whose engines are propelled by atomic reactors. Al o in the near future atomic energy will be used in space explorations making a direct opening for interplanetary travel. Statisticians all over the world are making great contributions to the advancement of mankind. Exploration of the universe is going on and it has been made easy by the launching of new satellites. Worldwide Television is another of the latest additions to the technological advancements. Through the Telstar Satellite launched by America, the first worldwide Television came into being.

A Scientific education always helps to rationalize ideas. As undergraduates of Science, it becomes necessary in the society we live in today to take note of the far reaching events, occurring around us. Science can only play its full part in furthering the welfare of mankind if it is used at a very early stage of education as a means of encouraging a dispassionate but optimistic attitude towards all aspects of human affairs.

People like to imagine that because all our mechanical equipment moves so much faster, we are thinking faster too.

Christopher Morley.

What is beautiful and definite and the object of knowledge is by nature prior to the indefinite and the incomprehensible and the ugly.

Nicomachus.

We have found a strange footprint on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last we have succeeded in reconstructing the creature that made the footprint. And lo ! it is our own.

A. S. Eddington.

If you can meet with triumph and disaster
And treat those two impostors just the same....
If you can talk with crowds and keep your virtue,
Or walk with kings—nor lose the common touch....
Yours is the Earth and everything that's in it,
And—which is more—you'll be a man my son.

Kipling.

Benevolence is a natural instinct of the human mind; when A sees B in distress, his conscience always urges him to entreat C to help him.

Sydney Smith.

SPACE AND CEYLON

By Arthur C. Clarke

It may seem unlikely that Ceylon will be able to benefit directly from the enormous space programmes now under way in the United States, the U.S.S.R., and elsewhere. However, this is not the case and there is one way in which this country could derive the greatest possible benefit from these programmes. An opportunity has now arisen which, however, will pass swiftly unless advantage is taken of it in the very near future.

For technical reasons, which I shall explain later, all the countries involved in space research are vitally interested in obtaining Equatorial bases, both as launching sites and for tracking and communications equipment. A search is now in progress for suitable sites around the entire equatorial region of the world. So important is this that the U.S. Space Administration recently signed a contract with the Italian Government for the establishment of a *floating* launching site (a converted oil-drilling rig) to operate in the Indian Ocean off the East coast of Africa. Obviously only small vehicles could be launched from such a base, and there are many grave disadvantages in operating at sea. However, the fact that such a project is even being attempted indicates the importance placed on equatorial sites.

In addition, the British Government has been conducting a survey of such sites as launching bases for a proposed communication satellite system, using the BLUE STREAK vehicle. According to recent press reports, one of the sites favoured is the Seychelles (latitude 5 South). Other locations proposed have been Brazil and Somaliland.

There is probably no location which exactly fulfils all the requirements for a launching ite. These are :—

(1) At least a thousand miles of open sea to the east, so that descending booster stages cannot cause damage.

(2) Easy access, especially good harbour facilities.

(3) Good weather—particularly freedom from hurricanes.

(4) Ample electrical power.

(5) Political stability, since a major launching site involves an investment of thousands of millions of rupees.

(6) The local availability of large numbers of workmen, technicians, and scientists, together with a fair degree of industrial development.

The reason why the equatorial zone of the earth is of unique importance for the future of space technology is as follows :—

(1) Space vehicles launched from the Equator in an eastward direction already possess an initial velocity of 1,000 m.p.h. by virtue of the Earth's spin. This permits rocket-fuel economies not possible with launching sites at higher latitudes.

(2) It is only from the Equator that the whole of the celestial sphere is visible during each 24-hours. In higher latitudes, parts of the sky are permanently invisible, being blocked by the solid body of the Earth itself. Thus the equatorial region is ideally suited for tracking stations (both optical and radio).

(3) *All* satellites, whatever their orbits, are compelled by the laws of celestial mechanics to pass over the Equator twice in each revolution round the Earth. Thus equatorial tracking stations have a better chance of observing satellites than stations at higher latitudes. In fact, low-altitude satellites in the equatorial plane can *only* be observed from the Equator, and pass over every point on it once every 90 minutes.

(4) For many applications, especially those in the field of communications and meteorology, it is necessary to use satellites which appear to be fixed in the sky ('Synchronous satellites'). As was pointed out by the writer in 1945, it is only by means of such satellites that it will be possible to establish a broadcast radio and TV service over the whole globe. For fundamental dynamical reasons, such satellites *must* be above the Equator.

The first such satellite (Syncom II) was orbited by the U.S. this summer. Though extremely successful, Syncom is not quite fixed because it was launched from Florida (28 N) and the carrier rocket did not have enough power to make the necessary latitude correction. Had it been launched from the Equator, Syncom would have been truly synchronous remaining stationary over one spot on the Earth, instead of oscillating over a 60 North South band.

Satellites launched from high latitudes can, and undoubtedly will, be steered into equatorial orbits, but the manoeuvre involves a considerable fuel and weight penalty (in addition to loss (1) mentioned above). For the space programmes of the near future, which will require the injection of many tons of payload into equatorial orbits a launching site on the equator could result in savings running to hundreds of millions of dollars a year.

When these facts are considered, it would seem that Ceylon can put forward quite a good claim as being suitable for an equatorial launching site. Certainly, in almost all respects, it would be greatly superior to the Seychelles, which are very small, relatively undeveloped, and do not even have an airport. Of course, Ceylon is not exactly on the Equator, but nor, for that matter, are the Seychelles; a few degrees north or south are of minor importance.

Ceylon is also an ideal site for a tracking station, since it is the last land outpost in the enormous, empty expanse of the Indian Ocean. The worldwide MERCURY tracking network, which is financed by the United States but operated by local technicians and scientists, has no fixed station between Africa and Australia. So far the gap has been plugged, at great expense and inconvenience, by a special ship cruising in the Indian Ocean. A station in the south of Ceylon could go far to filling this gap—for the benefit of *all* countries launching space vehicles, which need such tracking stations badly.

There is hardly any branch of pure science or engineering which is not now intimately involved with space research, and which is not receiving a major impetus from progress in astronautics. In addition, great social, cultural and commercial benefits are expected in the near future from such space applications as the communications and meteorological satellites. The first will start to bring direct TV to the whole of Asia and Africa some time in the next decade. The second will greatly improve the accuracy of weather forecasts, expecially in countries such as Ceylon.

In Washington recently, my friends in the Space Administration gave me the first TIROS Meteorological Satellite photograph of the whole of Ceylon and Southern India, taken from a height of about 500 miles. It showed a wealth of weather detail (including the extent of rain areas) of which the Department of Meteorology was unaware, since it has no means of obtaining observations far out in the Indian Ocean. Reliable weather forecasting would be worth many millions a year to this country, and will *only* be obtainable with the help of satellites. (Incidentally, while this article was being written, TIROS VIII was launched. This will broadcast weather pictures to stations in India, and these may be of the greatest value to this country. I hope that steps are being taken to acquire them even if we are not able to instal ground equipment for the direct pick-up ourselves.

Apart from the direct scientific, cultural, technological and ultimately commercial pay-offs of a space programme, it has many secondary benefits. It acts as a great stimulus to all scientific and intellectual activity, as well as to the economy of the region involved. The psychological effect of being part of a dramatic human enterprise is also considerable, and the operation of even a modest tracking station can make a major contribution to a country's scientific stature. And as for the impact of an international launching site, funded by the Americans, the Russians and ELDO (the European Launcher Development Organisation) to the extent of a few thousand million rupees a year—I leave that to the imagination!

[This article appeared originally in the December 1963 issue of INDUSTRIAL CEYLON.]

For "is" and "is-nots" though with rule and line
And "up-and-down" by logic I define
Of all that one should care to fathom, I
Was never deep in anything but wine.

Ah, but my computations, people say,
Reduced the year to better reckoning ?—Nay
'Twas only striking from the calendar,
Unborn tomorrow and dead yesterday.

Omar Khayyam.

WHY THE SKY IS DARK AT NIGHT

By D. A. Mendis
(*Asst. Lecturer in Mathematics*)

Why is the sky dark at night ? This question might seem very trivial at first sight, but it is one of the cornerstones of modern cosmology, and it may be claimed without exaggeration that it was the attempt of the German Astronomer Olbers to answer this question about 140 years ago that first made cosmology a Science. For his was the first cosmological theory that attempted to predict observable phenomena.

In a remarkable paper published in 1826, Olbers set out to calculate the intensity of radiation reaching us from distant stars at night. He realised that in order to do so he would have to consider effects from regions too far away to be seen in detail, and therefore had to make assumptions regarding the nature of the depths of the Universe. The assumptions he made looked very plausible till recent times and even today would serve as a model of what the beginning of a scientific investigation should look like. The deductive reasoning therefrom, however forced him to the ridiculous conclusion that the sky cannot be dark at night ! and since the rigour of his argument seemed to be unimpeachable his result was referred to as Olbers paradox.

I shall first present his own argument in the light of Astronomical knowledge of his day and proceed to show how the subsequent efforts to resolve this paradox led to greater and greater understanding of the nature of the Universe, and how its final resolution forced upon us the conclusion that the Universe as we know it, either had a beginning or is expanding or both.

The first assumption that Olbers made was that the distant regions of the Universe look very much like our own. In particular that the average density and the average intrinsic luminosity of the stars do not vary throughout space. This assumption was in full accord with the ideas that were current since the time of Copernicus, that there is nothing special about our position in space. This is also a very fruitful assumption to make from the Scientific point of view since we can then take that what goes on around us goes on everywhere else as well, at least in average if not in detail.

This assumption was insufficient for the calculation Olbers wanted to make, for light travels at a finite speed and so the light we receive now was sent out by distant stars a long time ago. What is therefore important for our calculation is not how much the distant stars radiate now but how much they radiated at the time they sent out the light reaching us now.

So Olbers had to make an assumption regarding the variation of astronomical conditions with time. Here too he made the simplest, that at distant time the Universe looked very much like what it looks at present particularly in relation to average density and luminosity.

In other words he assumed that we were getting a typical view of the Universe not only in space but in time as well.

Next Olbers assumed that the laws of Physics as we know them apply everywhere else in space and at all times. This too was a completely legitimate assumption. In fact anything else would be untenable for we cannot set out to find the nature of the depths of the Universe by first discarding all the knowledge we have gained from our neighbourhood.

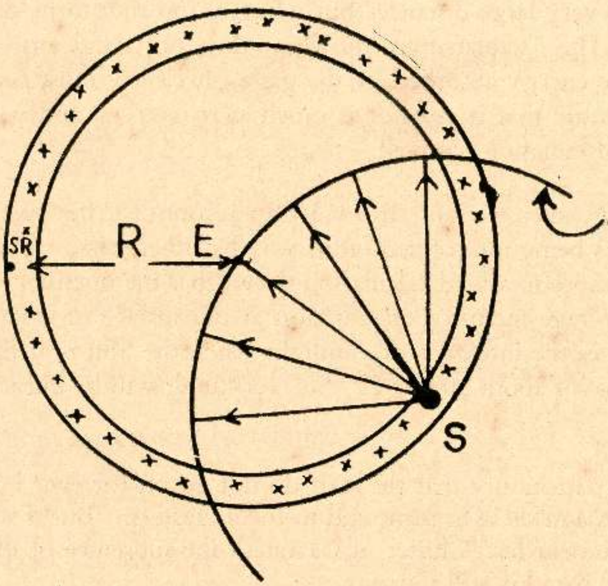
He also made the implicit assumption that space was Euclidean and that there are no large scale systematic motions of the stars i.e. that the Universe was static.

On the basis of these assumptions let us calculate the intensity of radiation received by us from the stars.

Imagine a vast spherical shell of radius R and thickness δR with the earth as centre. (We suppose that δR is small in comparison with R but large enough to contain a large number of stars within the shell). Let N be the average density of the stars, and L the average intrinsic luminosity of the stars.

Then since the volume of the shell is $4\ \pi R^2\ \delta R$, the total radiation from within the shell $= (4\ \pi R^2\ \delta R)\ NL$.

The radiation from each star has spread over a sphere of radius R in reaching us (as shown in the following diagram).



Sphere over which radiation from star (S) has spread by the time it reaches Earth (E)

Therefore the intensity of radiation at the centre (Earth) due to the shell

$$= \frac{4\ \pi R^2\ \delta R.NL}{4\ \pi\ R^2}$$

$$= \delta R.NL$$

which is seen to be independent of the radius of the shell.

If we therefore add up the intensities due to successive concentric shells the intensity at the centre (Earth) gets built up without limit.

So the intensity of radiation received by us can be made extremely large. In fact if we sum to infinity, the intensity (I) of radiation received by us

$$= \int_a^\infty NL\,\delta R = NL \int_a^\infty \delta R = \text{infinity}.$$

Even if we do not sum up to infinity but only up to a moderately large value of R the intensity becomes so great that it cannot be dark at night.

This argument is a prototype of Scientific arguments. We set out assumptions and deduced from logical argument consequences that are susceptible to observations (namely the intensity of radiation received). But we have found that the observations do not agree with the forecasts of the theory.

The next thing then is to see whether we have neglected to consider certain other aspects which may have a bearing on the problem, and thereby try to expla n away the contradiction obtained.

Olbers suggested that there may be an extremely tenuous gas between us and the stars absorbing the radiation in transit over very large distances but which is too thin to be detected by astronomical observation. This "explanation" however does not stand serious investigation, for, what happens to the energy absorbed by the gas ? It clearly must heat the gas until it reaches such a temperature that it radiates as much as it receives, and will hence have no effect on the intensity of radiation received.

Another possible explanation exists, since we have also failed to account for the possibility of the radiation from distant stars being intercepted on its way by other stars. If we include this factor however a slightly more involved calculation shows that the intensity of radiation received by us equals the average intensity of radiation at the surface of a star, (which works out to about 50,000 times the intensity of Sunlight when the Sun is at the zenith and a corresponding temperature of about 10,000°F. So everything will be burned up !)

We know in the light of modern astronomy that the stars do not go on for ever but form large aggregations called Galaxies and these in turn tend to form clusters. But if we replace the word "star" in Olbers argument by "Cluster of Galaxies" the substance of the argument is in no way affected and the paradox still remains.

We are then forced to the conclusion that one or more of Olbers assumptions are wrong.

It is untenable to discard the assumption regarding the applicablity of the laws of Physics to distant parts of the Universe for then there are so many possibilities with practically no guidance in discriminating between them, that it hardly seems a very scientific approach.

We also cannot discard the first assumption without assigning a special place to us in space (*i.e.* going back to a Pre-Copernican view). So we have to consider discarding one or more of the others.

We will first discard the assumption that space is Euclidean.

Suppose space is Non-Euclidean, it must still be homogeneous. (This follows as a corollary of the first assumption). Then the Non-Euclidean nature of space will manifest itself in the form that the surface area of a sphere of radius R drawn about the Earth as centre is not $4\ \pi R^2$ but some function of R, say $f(R)$.

Then the intensity of radius received at the centre

$$= \frac{f(R)\ \delta R\ NL}{f(R)\ \delta R} = NL\ \delta R \quad \text{which is the same as before.}$$

The paradox follows even if we cannot take arbitrarily large R due to our Non-Euclidean space "Closing up on itself." For then we would be receiving radiation from previous periods of the Universe rather as great circles on a sphere can be continued arbitrarily far although the surface area is limited.

So the paradox exists whether space is Euclidean or not.

We are now left with two assumptions, the second and the last. The most likely one to be wrong is obviously the last (that the Universe is static). If we discard that, and postulate instead that the Universe is expanding we can resolve the paradox. For then the distant clusters will all be moving away from us, the greater the distance the greater being the speed of recession, and it is well known from ordinary Physics that radiation received from a receding source is reduced in intensity compared with that from a source at rest relative to the observer. So that the radiation reaching us from distant shells are tremendously weakened, when taking this fact into consideration.

L must be replaced by a function of R, say $L\ (R)$, we can then make

$$\text{I} = \int_{a}^{a} NL\ dR = N \int_{a}^{a} L\ (R)\ dR,$$ converge to the observed value, by postulating a certain rate of expansion.

If we discard the second assumption instead we can again resolve the paradox by postulating that all the stars are younger than a certain definite age. For then the radiation from distant shells would not have reached us still, giving rise to a "cut off" at a certain distance which equals the distance light has travelled from the oldest stars. So we can once again obtain the observed intensity of radiation by postulating a definite age to the Universe.

So in order to resolve Olber's paradox we have to assume that either

(*a*) the Universe is expanding
or (*b*) the Universe as we know it, is young
or both (*a*) and (*b*).

That the Universe is expanding has been subsequently deduced from the Doppler shift observed in the spectra of Galaxies. But whether the Universe as we know it had a beginning or whether it exhibited the same unchanging aspects for all time is as yet an unsettled Cosmological question.

Whatever may be the case the really remarkable thing is that so interesting and significant conclusions as (*a*) and (*b*) can be drawn from so simple an observation as the darkness of the night sky.

SOME REFLECTIONS ON THE PROGRESS IN METALS

Dr. P. P. G. L. Siriwardene
(*Lecturer, Department of Chemistry*)

The use of metals dates back to about five thousand years ago and since then their influence has been so dominating that we can assess civilization as we know it in terms of the metals that we use. Since early times metals have been used for their artistic value as ornaments and also as tools, implements and weapons. Copper was one of the first metals to be used in large quantities and gold also dates very early although on a very small scale. Iron and steel came into use later and with the work of the Ironmasters in the eighteenth century and the large scale production of steel by Henry Bessemer in 1856 iron and steel have contributed in a large way to the increasingly enormous quantities of metal that came into use.

Metallurgy, the art and science of metals, includes the extraction and refining of metals, the production of alloys, their treatment and fabrication and the study of their structure and properties. The production of alloys has progressed so fast that many new alloys are coming into prominence almost daily to provide the material suitable for the striking achievements of today. Special steels are required to withstand the high temperatures encountered in rockets and space craft, to withstand the repeated stresses that cause fatigue failure, to withstand changes in dimension that cause failure by metallic creep, to withstand the corrosive environments in which metals are expected to be used, and so on.

An aspect in the progress of metals that is particularly important is our understanding of the structure of a metal or an alloy. We know that a metal consists of positive ions immersed in a sea of electrons or 'electron cloud' and this electron cloud holds the metal ions together. This is a simple qualitative picture. We also know that an alloy is made up of two or more metals and that alloying elements can also be metalloids. A metalloid has properties both of metals and non metals and carbon and silicon are two good examples. Alloys could be of two kinds, substitutional alloys and interstitial alloys. In the former kind one atom is substituted by another as for example in an alloy of copper and zinc or iron and nickel. In the interstitial type we have small atoms fitting into the gaps or interstices between the parent atoms and an example is the entry of carbon atoms into iron.

Our knowledge of metals and alloys has progressed with the invention of the metallurgical microscope. As thin enough sections are not possible for examination by transmitted light, the principle of the metallurgical microscope is to examine by light reflected from the specimen. The metal specimen has first to be prepared for examination by polishing followed by etching of the artificial surface caused by the polishing. This brings out the underlying structure which is observed under the microscope. The etching is done by using specific chemical reagents. For example, nital i.e. nitric acid in alcohol is quite common for examining steels, or a solution of ferric chloride is useful in the case of brass. The optical microscope has its limitations and a magnification of about —1500 is possible, an oil-immersion lens being used for the higher magnifications. It is not only the magnification that is necessary but also the resolution, and the resolving power of an optical microscope is limited. A good resolving power makes it possible to see two objects very close to each other as distinct and separate whereas if the resolution is not satisfactory both objects would merge and appear as one. A light microscope where light has a comparatively long wave length has a limited resolution. If the wave length is shorter the resolution is improved. This led to the development of the electron microscope just before the last war. We know that electrons could behave as waves with a very short wave length as was discovered by de Broglie and others. The electron microscope is similar in principle to the light microscope but instead of a beam of light, a beam of electrons is used. This beam emanates from a heated filament such as tungsten and this unit is called the electron gun. The lenses instead of being of glass are electromagnetic lenses and the magnification is adjusted using different pole-pieces. Electrostatic lenses are also useful but these are not common. A very efficient vacuum has to be maintained so that the electron beam could travel and also be kept steady. The examination of metals using the electron microscope is by preparing replicas of the etched surface using a plastic materials such as polyvinyl aldehyde and by examining the replica in the microscope. Recent techniques have brought out other types of replicas such as oxide replicas in the case of aluminium alloys, and carbon replicas. Electron microscopes where the metal itself can be directly examined using reflection are now being developed so as to avoid the inaccuracies of using replicas.

Microscopy will often only give a qualitative picture of the constituents but may not be useful in identifying these constituents. In this direction X'rays have become an important tool in the study of structure. The use of X'rays where X'ray diffraction patterns are obtained enables one to identify the components from the patterns. One could also say more about the structure as for example the nature and dimensions of the metal crystal itself. The microscope would show the larger dimension of metal grains whereas X'rays reveal the finer structure as they penetrate right down to the fundamental atomic structure and show the arrangement of the atoms in the crystal.

The development of the theory of the nuclear atom and the application of the quantum theory to the motion of the electron, has led to the fact that electrons circulate in chosen orbits. These orbits are restricted by the condition that the energy changes from one orbit to the next only in certain finite values. In addition there was the later discovery of the wave nature of the electron and the development of wave mechanics. A result of this was that it was not possible to know at once both the position and the velocity of an electron. The most we could know is the probability that an electron would be in a given space. The atom was a nucleus surrounded by a diffuse cloud of negative charge, the density of charge at each point being proportional to the probability of finding an electron there and varying in such a way that the density was great at the nucleus and small at a distance, with a number of intermediate maxima. It was also possible to find the ways in which the electron cloud altered when another atom came near to it. These alterations would sometimes cause an increase in the total energy of the cloud and sometimes a decrease. When there was a decrease, the two atoms would be attracted and be linked to each other. In this way chemical combination and the cohesive forces between atoms in solids can be explained and what was more, it became possible to make calculations about the strength of metals. Our picture of the metallic crystal is of atomic nuclei oscillating about mean points in three-dimensions, each nucleus being surrounded by its electron cloud.

When we consider the progress of metallurgy as a science we cannot forget the pains-taking work of Heycock and Neville who in a basement room at Cambridge University worked out many phase diagrams and applied the Phase Rule to several binary alloy systems. Today we have a range of these phase diagrams, for practically all known alloys. These are temperature—concentration diagrams which enable us to see at a glance what we should expect for a particular alloy composition at a particular temperature. This is extremely useful in the heat treatment of metals and alloys. It may be worthwhile to mention that heat treatment would alter the structure and the structure is correlated to the mechanical properties. Examination of a structure could therefore often easily indicate the particular good or bad qualities of a metal and whether it is satisfactory for a particular purpose and of course it will also enable one to explain why a particular metal has failed. Failure of metals can be due to various causes such as bad material itself or bad fabrication or phenomena such as metal fatigue, creep or corrosion.

In an article of this nature it is possible to consider only certain aspects in the progress of the study of metals and if one were to be more comprehensive there are the advances in the various types of heat treatment, the new high-temperature and corrosion-resisting alloys, the newer methods of extracting and refining metals, the modern methods of casting and working of metals, and so on. Foundry practice, rolling, tube drawing, wire drawing, forging, galvanizing, welding have all progressed very rapidly and are complete subjects in themselves.

I might however, deal briefly with another aspect which is not widely known. This is the field known as Powder Metallurgy which is the art and science of manufacturing useful articles from metal powders. The principle of this process was used long ago when the Egyptians reduced iron oxide with charcoal and obtained a spongy mass of iron which could be hammered and forged into various shapes. It was this same process that had been used in about 300 A.D. to make the Delhi Pillar which weighs about six tons. This Delhi Pillar is of interest in that it has withstood corrosion over all these years. Hadfield took a piece from this pillar back to England to study this peculiar behaviour but soon found the piece to corrode in the wet English climate. This illustrates the important bearing the environment has on corrosion. Ancient tribes of South America used powder metallurgy to produce platinum metal with which they made ornaments. During the last century several metals such as nickel and cobalt were made in powder form and sold as briquettes made by reducing the oxide with carbon, followed by sintering.

One of the first of the modern products of powder metallurgy is the tungsten filament wire used in electric bulbs. Tungsten powder was compressed into small bars and sintered. These bars were reduced in size to thin rods and from these ductile filament wire was drawn. Molybdenum and tantalum have been prepared in a similar way. Cobalt cemented tungsten carbide has been prepared by powder metallurgy to produce die material for drawing hard tungsten rods into filament wire. This was first done by the firm of Krupp in Germany and from this die has developed the present day hard-metal industry. Iron and steel components have been manufactured from iron powder at a cost comparable with parts produced by the usual methods of casting, forging and machining. The last war gave an impetus to the development of iron powder-metallurgy, particularly in Germany. Powder metallurgy is now a recognised procedure and is the best known method for manufacturing the refractory metals such as tantalum, tungsten and molybdenum. These are made by sintering their compacted powders. By using powder metallurgy special metallurgical structures can be obtained which result in unique physical properties. In certain cases sintering gives a better product than casting and for certain engineering components required in very large quantities powder metallurgy is an economical method of fabrication.

Before concluding it may be mentioned that instrumentation and analytical methods have improved tremendously with the greater production of metals and high-quality alloys. The metal industries are very old and traditional and our present day instruments were preceded by very vague and primitive methods of quality control. Temperatures were judged visually and this only confirms the importance of experience. There was a time when a temperature was judged by throwing a potato into a furnance and observing it after a time ! Metal industries require many modern instruments for such things as continuous dimension measurement, alloy composition determination, determination of coating thicknesses or the detection of flaws. Non-destructive testing of metals has developed to a very great extent and depend, among others, on the use of electrical and magnetic methods, ultrasonics, electronics and radioactivity. In the last mentioned there is the use of radioactive sources, such as Cobalt—60, in gamma radiography. The penetrating gamma radiation gives a picture of a metallic component on a photographic plate and shows any flaws if present in the material. Radioactive sources such as thallium—204 or Strontium—90 are used in thickness gauging. If the radioisotope is positioned on one side of the strip with a Geiger counter on the other, the radiation passing through to the counter will depend on the thickness. In this way one can ensure a constant thickness, and from the reading on the counter one will know when the thickness has altered. A firm in Ceylon has now installed a thallium thickness gauging instrument to control thickness in the metal strip and foil that they roll.

Metallurgical analysis involves the use of many chemical reagents ncluding a wide range of organic compounds and many new methods of analysis. One of the new methods is polarography devised by Heyrovsky in Prague and this is an electro-analytical method. Chromatography instituted by Tswett in 1906 is another technique widely used.

So many things clamour for inclusion in a survey of this nature but it is impossible to mention more than a few highlights in what has been a period of crowded scientific progress. The impression we have is that we and those who follow us are inheritors of a vast metallurgical knowledge and we can appropriately repeat an inscription displayed over a factory gateway in America that " Great things are being done in our time."

A SCIENTIFIC ANALYSIS OF WOMAN

Symbol—O.
+

Molecular Weight—$\simeq$ 100 lbs.

Occurrence—Exists wherever man exists.

Appearance—Nice from far but usually far from nice.

Specifications—A specimen is composed of a series of curves, (parabolas, hyperbolas and sine-curves) the amplitudes of which vary considerably with the specimen—(but even an eminent anatomist may be deceived by some of the artificial composite structures).

Chemical properties—Surface coating must be removed to obtain true specimen. Has great affinity for Gold, Diamonds and other ornamental products. Turns pale green when placed beside a better specimen. Extremely difficult to guage reactivity.

Physical properties—Coefficient of Restitution and Modulus of Elasticity is directly proportional to the curvature of the specimen. If left alone, becomes "radio active" and will beguile the hour provided with light music.

Special properties—Have a passion for mental arithmetic. Can divide their ages by two, double the prices of their latest dresses, treble their husband's wages and add anything upto ten to the ages of their fellow specimen friends.

Caution—Handle with care. Can be explosive if hair is rubbed the wrong way.

Advice to Males—Treat them like chemicals. Use them carefully—Once used, throw them away.

By GAMMA.

SCIENTIST, SCIENCE AND SOCIAL CHANGE

By a Marxist

Empiricism

The beginnings of modern science lie in the period in which trade and commerce began to play an important part in the economy of feudal Europe, and in which the class of merchants and traders who were to destroy feudalism were growing in power. The practical problems of manufacture and trade, of transport, building roads and canals, of navigation, of mining, lie behind the theoretical problems which Galileo, Kepler and Newton solved. Practical problems posed by nascent capitalism underlay their problems and the urgent need for solutions to these problems explains the rapidity of the development of science at this time.

The new science grew up, not with the support of the universities, but in face of their opposition and hostility. The centres of research were scientific socities, such as the Royal Society of London, set up for the purpose. Official science was based on the authorities of holy writ and the works of Aristotle ; it solved scientific problems by argument, or by consulting these works, not by experiment. So Galileo, writing to Kepler about the reception given to his new telescope by the local university professors, says :

'We must smile at the great stupidity of men. What are you to say to the first philosophers of the school here, who with the stubbornness of an adder, despite invitations a thousand times repeated, did not wish even to glance at the planets or at the moon, or even at the telescope itself. Truly the eyes of these men are closed to the light of truth. It is astounding yet it does not surprise me. This kind of person thinks that philosophy is a kind of book ...... that truth has to be sought not in the world, not in nature, but in the collection of texts.'[1]

Thus modern science has its roots not in any sort of materialism but in the new philosophy of empiricism.

Present Dilemma

In 1914 the continuation of political relations between the various capitalist countries of Europe required the use of 'other means'. Each of the advanced countries, fighting for a bigger share of the world market, used the most up-to-date machines and factories, the most modern developments of technology, in order more effectively to destroy innumerable towns and cities, lives and ways of life.

By the time the war ended, many scientists felt that they had seen enough of the applications of science to 'real life'; they took up the study of a branch of the subject which they felt to be particularly useless and remote from the needs of industry and war, atomic physics.

1. See "The Social and Economic notes of Newton's Principia" by B. Hessen (in 'Science at the Cross Roads', Kniga, 1931).

Professors and lecturers in remote and ancient university towns, collaborated freely with scientists of all other countries, all engaged solely in the disinterested search for the truth. The results of their search were the atomic bomb and the hydrogen bomb!

In the history of these weapons and of the men involved in the development of them, described by Robert Jungk, their dilemma can be clearly seen.[2] On the one hand, as scientists they have a vast influence on the life of every person on earth; on the other, however liberal and idealistic they may be (and very often are) as people, they have not the slightest control over the weapons they have invented, nor any power to prevent their use.

Scientists almost invariably attempt to resolve dilemmas of this sort by retreating further into the ivory tower of academic research. They see the separation of science from real life as its greatest safeguard, and the necessary condition for its progress. They dislike the way in which the state and the monopolies finance research mainly into fields which are useful to them in industry or nuclear strategy. They see their task as that of increasing our store of knowledge of nature, and leave aside the question of how their work affects the lives of people; and when the nature of the work makes this separation no longer possible, as happens today with the research into atomic energy or automation, they see its application only in an ideal world, in which atomic energy provides unlimited cheap power and automation free workers from drudgery and adds to their leisure, not in a world in which an atomic bomb destroys Hiroshima, and automation puts thousands on the dole.

Yet this attempt to reduce science to no more than the search for objective truth has never succeeded. The example of the atomic scientists shows this; and other examples are not hard to find. Thus the Marxist scientific analysis of history has been vindicated by the history of science. Science of a particular epoch, with the rest of its culture, has been a part of the 'superstructure' of that epoch and has served the interests of the class that was in power.

In the present epoch capitalism constantly uses their work in a way which is quite opposed to many scientists' ideal of progress; and yet which they seem quite unable to either understand or to prevent. When we look at the way in which modern science has developed, we see that science and especially the relation of science to society, is not something which is organised and decided upon in the best, or most reasonable, way. Like everything else, it is determined historically; and the history of science is not simply a list of discoveries and inventions which were used to get more discoveries and inventions; on the contrary it is a part of the history of society and its culture which Marx described as a history of class struggles.

Thus the rise of the new science did not lead to an automatic and unlimited development, either for science or for society. Just as the eternal moral principles, the laws of a rational society, laid down by the Enlightenment ended up by providing a justification for the power of the French bourgeoisie, so the history of science from the time of Galileo and Newton up until the present day, has shown it to be science adopted to the needs of capitalism.

2. See, "Brighter than a Thousand Suns" by Robert Jungk.

The new philosophy, empiricism, not only limited in advance the tasks of science but has perhaps advanced to the limits of its creative and constructive possibilities. In rejecting the arbitrary participation of the Creator in the day-to-day running of nature, the new scientists had renewed what had unified their understanding of nature. They said that all knowledge of nature came from experience, but what does the experience of the scientists consist of? It consists of observations of all the numerous different kinds of things in the world, and of the lawful, predictable behaviour of some of them. The job of scientists became one of classifying; measuring and finding the numerical laws suggested by a large number of related measurements; setting precise limits to fields of study, and observing the properties of and relationships between the characteristic kinds of things in the small part of nature thus isolated.

This process of defining the boundaries of any given science, of finding the laws which have autonomy in that particular science, and neglecting the effects on it of the rest of nature, is the necessary way in which scientific knowledge has been and is being built up. Nevertheless there are some questions which it does not answer. It says nothing about the essential connection between the different branches of science, a connection which arises out of the fact that all the sciences are different ways of understanding one world. It cannot explain *why* it is possible to understand this world, firstly as a system of electrons, protons, etc., in motion under their natural interactions, secondly, as various chemical elements, combining according to certain laws, thirdly as a collection of human beings, living in a class society, and so on.

Denying to science the possibility of finding the reasons in the real complexity of nature, empiricism is forced to bring them from outside science—in the form of religion or some more sophisticated variety of idealism. Newton, for example, opposed the idea that the development of science in any way put in question the responsibility of God for the existence and structure of the natural world. Again, Mack, towards the end of the last century, argued that the subject-matter of science was not the real world but meter-readings, subjective sense-impressions received by the individual brain, and in this way he reduced the enormous variety of natural law to conditions on the way in which these impressions were received, properties of the mind.

The scientist is, from this point of view, simply a passive observer, receiving signals from outside and fitting them into pattern which enables him to predict the results of experiments, but knowing nothing of the connection his signals and the real processes going on in the world. It becomes impossible for the scientist to say anything about the real nature of matter. This perhaps is more evident in the case of modern physics.

The great advances which physics has made have resulted from a process of constructing models of the world, or of small parts of it, in each of which all the relevant phenomena have been supposed to result from the motion and interaction of a small number of different kinds of things. Each model has in turn been discarded and replaced when it has been found to qualitatively over-simplify the real world.

From the point of view of empiricism, it is meaningless to say that the processes occurring in the model reflect actual processes going on in nature; the criterion becomes that the model should be the simplest which adequately explains the results of experiments. In practice, furthermore, the current theory is always thought to contain at least the essential features of the ultimate theory of matter. Thus the history of physics is not understood as this process of 'approximation of thought to the object'; instead, to paraphrase Lenin again, 'the reflection of nature in man's thought' is understood 'lifelessly, abstractly, devoid of movement, without contradictions'.[3]

From a materialist point of view, a good model which predicts accurately the results of experiments also reflects more or less faithfully the actual processes occurring in the real world. The continual construction of such models and, from the contradictions between them and the real world, deriving new ones, is the process in physics of the 'eternal, endless approximation of thought to the object'.

Hence the arguments of empiricism taken to their logical conclusions (with which only a very few scientists would agree), reveals how science loses its active role, of harnessing the forces of nature in order to transform the world in man's interest. Yet it is just the ability to see this active role of science, including social science, in a world seen as a whole, which leads to the view of present society, not as anything permanent or necessarily as it is now, but as a stage in the history of society which must be passed. The dilemma of scientists which we mentioned is the result of the lack of this understanding. Without it, even if their research is not restricted, controlled or directed in any way, its results can be appropriated by capitalism, just as it appropriates the products of the factory worker.

Dialectical Analysis

As modern science evolved not merely great advances in methods and techniques, but also a completely new way of looking at the world and man's place in it; a revolution in thought occurred, in fact, accompanying and justifying the revolution in science. Many of its characteristic features have their origin in the revolution in thought which accompanied and justified the dourgeoisie revolution. The new philosophy removed the creator to a safe distance, invisible, unknowable and without observable consequences, and made the investigation of the world of our senses the province of the scientist, of observation and experiment. It made possible the vast development in science and technology which has transformed what was previously a world of man's perpetual struggle for existence into a man-made world, hardly any part of which has not been constructed or adopted by man for his own purposes.

Georg Lukacs in his recently translated book on the historical novel compares the situation of the scientists in capitalist societies with that of the writers.[4] Lukacs' theme is, very briefly, the new understanding of history shown by the great writers of the period of the bourgeoisie revolution in Europe, and the decline of this understanding after 1848, during the consolidation of bourgeoisie rule and, subsequently, of the growth of imperialism. Authors such

3. V. I. Lenin, Philosophical Notebooks, p. 195.

as Scott derived from the revolutionary reorganisation of society which was taking place in their own time a clearer picture of change in history. They saw the progressive and reactionary forces which were peculiar to the past societies and communities of which they wrote and which worked to change them (and which through such changes, connected them with the present). Because of this connection, history for them was real and knowable. We see here, from a different angle, the new consciousness of man's power to control nature : for the scientist of the bourgeoisie revolution, concious of his power to harness the forces of nature for his own use; for the great novelist, consciousness of his ability to make his own history. This understanding arose when a revolutionary class showed in practice how it was possible for men to change the world.

As the bourgeoisie lost its revolutionary aims, so this consciouness and historical sense were lost. History no longer leads up to and explains the modern world; instead the historical themes treated present a world which is remote exotic, unconnected with today. The forces which change the world are again unknown and unknowable; they reveal themselves only as the subjective wishes of great men.

Unable to recognise and accept the historical role of the *proletariat* after the bourgeoisie revolution, the later writers were unable to see for themselves the possibility of change. Consequently they saw in history only the difference from, not the connection with, the present.

In the same way, the materialism of many of the earlier scientists turned into the idealism of Mach and Eddington. As the ruling class was less able to use the results of science in the interests of men, so scientists became less and less confident of their ability to control nature, of the understanding of nature which their science gave them.

The development of the historical novel, from an important way of understanding society and the way in which it changes, into a particular brand of escapism like the detective novel or science-fiction, is therefore closely paralleled by the development of science, which changed from the search for ways to harness nature into an academic pursuit, science for its own sake, independent of the use to which it is put. Neither makes any statement about the nature of society or of the natural world, whose workings remain unknowable. Both are the typical products of the period of capitalist rule.

Like the novelists with whom Lukacs deals, scientists also have been led to reject bourgeoisie society's way of using their work; expecially, in their case, during the present century, in which imperialism has employed nearly all the great achievements of science in destroying, expropriating or exploiting the mass of the population of the world. Again, this rejection is limited by the position of scientists in this society, and by their partial, one-sided view of the world, which we considered earlier. As imperialism increases the gulf which separates the progressive possibilities inherent in science from the uses to which it is put, so it accelerates the negative, idealistic tendency of empiricism. The increasingly obvious inability of scientists to control nature in practice is reflected in their growing belief that their science provides only a shorthand description of an unknowable 'outside world' as it affects their instruments and meters.

4. G. Lukacs 'The Historical Novel', Merlin Press, London 1962.

Scientists, too, understand the possibility of great changes in nature and society only when this possibility is demonstrated by a revolutionary class which, in taking power, alters the whole economic, cultural and scientific organisation of society, giving them new freedom and setting them new tasks. Their present fragmented, compartmentalised science cannot itself arrive at consciousness of the possibility and the source of change in a society which seems to them permanent and static. This is provided, not by any impartial and objective analysis of laws and trends in nature and society, but by the understanding that the interests of science and scientists are those of the working class in the capitalist world, and only to the extent that this class successfully fights for a socialist society is any future progress guaranteed.

The power of Marxism, its capacity to become 'a material force,' all scientists conscious of their mission must realise, results from its relation to the working class. Marxism has the essential role in the history of the twentieth century. Only the international Marxist movement can provide the working class with the conscious scientific understanding of its power as an independent force to reshape society, and mutually, can make the new scientist realise his new role in that new society. The building of that movement is thus the highest point of theory and of practice.

Communism will not return to the primitive conditions which preceded the history of class society, but will embody in a conscious, planned way all the gains made by humanity. In the same way, Marxism unifies theory and practice without discarding the conquests of philosophy (which was the expression of their separation) and of science. The working class with achieve power only by negating philosophy, while grasping in practice the theoretical advances which the separation of theory from practice brought forth.

Communist man will make his own social life consciously. Natural science will no longer conflict with an irrational social environment, but will be rationally controlled in the service of man.

The working class, through its conscious vanguard, must become heir to the science, art and philosophy which class society has produced. The titanic struggles, to grasp the reality of the natural world and of man himself, of the Aristotles, Shakespeares, Hegels and Einsteins will be taken to a new and higher level by the socialist revolution.

There was a young fellow from varsity
Who tried to work out $\sqrt{\infty}$
But the number of digits
Gave him the fidgets
He stopped maths and up Divinity.

Miss Biso Menike is fair and bright
Her speed is faster than that of light
She started one day
In the opposite way
And came back the previous night.

THROUGH A TELESCOPE

(by an observer)

I work out the facts and start the practs
Galaha road comes to the cross wise
I take a look throw away the book
For the readings they go lepwise.

Many girls nice from far, I see one far from nice
And they are the ones who raise their price.
Pappadams I compare to their faces fair
Crisp one moment, stale the next, then beyond repair.
They dress in haste, and apply the paste,
And the result is to much make-up;
It's a waste, to think of their state,
When after a nap they make up.
Some have Skirts up to their toes,
And tie it to look like a Sack of potatoes
Rest show a flair for the country air,
For they leave their pretty (?) mid-riffs bare;
Should the mosquitoes war declare,
They'll have to hide, (the damsels fair).
To Catch the eagle they make their hare
Match the tail of a mustang mare;
As a set they are fricky,
As a bet they are risky.
And point and paint their nails their
To hook and look like a polar bear.

Alas my observations must end there,
For a Don comes from I know not where;
"Your observations don't agree with mine
Rotate telescope through $\pi/2$
And I bet it will be fine."

ELEMENTARY PARTICLES

DR. CHARLES DAHANAYAKE
(*Lecturer, Department of Physics*)

To the early philosopher, the universe was made up of the four "elements" : earth, air, fire and water. With the development of chemistry, however, it became clear that all matter consisted of combinations of some ninety odd different substances. Each of these could not be broken down further and hence truly earned the name element. Chemically speaking, the smallest part of an element is the atom and the atoms of one element were considered identical.

Even as early as the latter half of the last century it became clear that the atoms are not so elementary after all. Thomson had studied the nature of cathode rays and shown that they consisted of very light negatively charged particles travelling at great speed. Named electrons, they were found to be a common constituent of all matter. Spectroscopists had shown earlier that each element emitted a characteristic spectrum of light also indicating an inner structure for the atom. Around the turn of the last century, the discovery of radio-activity by Becquerel showed the spontaneous break-up of atoms.

Further investigation showed that the lightest of the elements, hydrogen, had a postive core known as a proton. The proton was considered to be the building block for all other atoms. This view was supported by the experimental observation that the atomic weights of nearly all the elements are approximately whole numbers. According to Thomson's classic "plum pudding" model, the atom consisted of the requisite number of protons and an equal number of electrons kneaded together like plums in a pudding. This may sound fantastic now, but the highly successful electromagnetic theory of radiation seemed to favour such a model.

Two fundamental developments altered this simple scheme profoundly. One was the introduction of quantum theory by Planck in 1900. The other was the elucidation of the structure of the atom by Rutherford through observations on the scattering of α—particles by atoms. He found that the atom was mostly empty and consisted of a heavy positively charged nucleus which accounted for nearly all its mass surrounded at relatively great distances by sufficient electrons to make the structure as a whole neutral. Bohr synthesised these ideas to expound a theory of the atom where he compared the atom to a miniature solar system. Bohr was able to explain the emission of radiation on the basis of new concepts.

The number of fundamental particles required by the physicist in the early twenties to explain the formation of the universe was few. Consider just one atom of a particular element. If it were an atom of mass A and atomic number Z, its nucleus had A protons and A-Z electrons having a net positive charge Z for the nucleus. This was surrounded by Z electrons at various distances, travelling in their prescribed orbits. To these two fundamental particles known at that time we may add the photon or the light quantum which had first been postulated by Planck and given further character by Einstein.

Though the situation looked satisfactory, the theoretical physicists were unhappy about having to lump electrons into the nucleus. Heisenberg's uncertainty principle showed that this was similar to asking a mischievous bunch of kids to stay quietly in a tiny room. All indications were that electrons would simply get out and run. It was therefore a relief when Chadwick, in 1932, discovered the neutron, a particle of mass very nearly that of the proton but having no charge. There was no further need to force electrons into the nucleus.

About the same time, Pauli had suggested the existence of a new particle to account for the apparent lack of energy balance in β decay. In the transformation of certain radio-active nuclei, β-particles (high speed electrons) are emitted with a wide distribution in energy. Conservation principles required that apart from the electron another particle was also emitted in the process. The new particle was expected to have neither mass, nor charge and very little interaction with matter. It was called the neutrino.

Meanwhile, Dirac the famous British theoretical physicist had worked out the theory of the electron. According to his theory there should not only be electrons but also particles exactly identical to them except for the charge—positrons. Further he predicted that the positrons and the electrons are always created in pairs, and that they would destroy themselves also in pairs. Confirming these theoretical predictions, the positron was discovered in cosmic rays by Anderson in 1932. Cosmic rays refer to the continuous rain of particles from outer space on the earth's atmosphere. We will later see that cosmic rays have given us a chance to discover many more fundamental particles.

If one looked back at the list of fundamental particles in 1935, one would have seen the following : electrons, positrons, photons, neutrinos, protons and neutrons—already a fairly formidable number compared to the two constituents of the plum-pudding atom. Though the physicists had heaped together so many protons into the tiny volume of the nucleus, they could not quite account for its stability. Anybody having the most elementary knowledge of electricity knows that like charges repel each other. However, experiments on scattering had already shown the existence of a short range strong attractive force-the nuclear force—between the particles in a nucleus. This force was found to be independent of charge and to drop off very rapidly with the distance of separation.

It was left to the Japanese scientist Hideki Yukawa to put this knowledge on a theoretical footing. We must also remember that by this time physicists had developed a powerful mathematical tool—Quantum Mechanics. In this there are certain fundamental mathematical equations which contain within them all the basic physical laws. At least, when they are properly applied they do account for what is observed. Yukawa fed into these equations his ideas on the nuclear forces. He found that the nuclear force was mainly brought about by the presence of a new particle. He estimated its mass to be about 300 times the mass of the electron and that, if isolated, it would live for about one hundred millionth of a second.

This was a very novel idea. Just as when some soap solution is stirred bubbles are created, so also when nucleons—i.e. protons and neutrons taken together—are stirred together these new particles, called mesons, are created. They dart from one nucleon to another and thereby help to keep them together. They give rise to an "exchange force" between the nucleons. While the exchange force does not totally account for all the features of nuclear forces it was a very significant development. Professor Yukawa suggested that the meson was much like the tennis ball which keeps the players on the court. The meson, however, lives only a phantom existence because it robs the particle it leaves of the mass needed for itself so that now one and now another particle will grab for it to become a self sufficient nucleon. If we want to see it in reality we must provide some means whereby the meson can have a right for independent existence. This is done by providing the mass in the form of energy on the basis of Einstein's theory of the equivalence of mass and energy.

There was a difficulty. Where can one find projectiles of sufficient energy to shoot at the nucleus ? The energy equivalent of the mass of the electron is about half a million electron volts (Mev). On this basis, a meson needs about 140 mev for its mass. Though several particle accelerations had already been developed, these could reach perhaps a few tens of Mev. Cosmic Rays on the other hand had tremendous energy. They have energies which are thousands and millions of times higher than can be produced artificially. It was therefore natural to look for the new particle in cosmic ray-induced interactions.

About this time cosmic ray studies had shown that the particles observed at sea level due to cosmic rays in the atmosphere contained a very penetrating particle of mass intermediate between that of the electron and the proton. Unfortunately closer examination of this particle—the μ-meson—showed that it does not have the other very important properties required by the Yukawa theory. So the search continued.

Some time after the last war, Powell in England was carrying out investigations into cosmic rays using specially sensitized photographic emulsions. These could record the tracks of nuclear particles After processing, the plates could be examined at leisure. Powell exposed some plates at the top of the European Alps. In some of these plates he observed tracks of particles which had masses of the right magnitude. Furthermore, from the end point of the track of such a particle the track of another slightly lighter particle was visible. The latter particle in its turn gave rise to an electron. Powell's explanation was as follows: In high energy nuclear collisions of cosmic rays near the top of the atmosphere, nuclear force mesons—called π-mesons—are created. These decay into the lighter μ mesons which later decay into electrons. This explains why the μ-mesons are predominantly observed at ground level. The μ meson has little interaction with nuclear matter and can go through some metres of lead with ease. They are found even in the deepest mines, having passed through the intervening layer of earth.

While Powell was studying cosmic rays with the help of emulsions, others for a long time had been doing the same using other techniques. One such technique is the cloud chamber, a clever device designed first by C. T. R. Wilson. In this a saturated vapour is induced to condense along the tracks of charged particles thus making the tracks visible.

Rochester and Butler in Manchester, as early as 1947, had observed in their cloud chamber tracks of particles which appeared to have masses about 1000 times the mass of the electron. More accurate measurements confirmed this discovery. In contrast to the π mesons these particles came to be known as heavy mesons. Heavy mesons are created directly in high energy nuclear interactions and therefore have strong interaction with nuclear matter. Soon after their discovery, emulsion workers added to the knowledge of the heavy mesons, by accurately measuring their masses and by showing that the particle decayed in a variety of ways. The heavy mesons were named depending on how they decayed and so was born the group of heavy mesons : τ, θ, K, $K\mu$, $K\beta$ and others. This is a complex group indeed but modern theory has managed to show that these can be classified broadly into two families. They are like the children of a family who while they may later become lawyers, doctors, engineers or teachers, all have the same ancestry.

Along with the discovery of the heavy meson, evidence came for the existence of a still heavier particle, in fact heavier than the nucleon. At the beginning, these were given the descriptive name of V-particles since they showed a characteristic V-shape at the decay point. Some of the early V's had in fact been heavy mesons. But there were ones which obviously had much higher mass, for they decayed into nucleons and π-mesons. Thus we have the Λ^0 particle which decays into a proton and a π-meson. In close succession were discovered the Σ (sigma) particles (three in number) and the Ξ (Xi) particles (two in number).

With this sudden abundance of particles the physicists were posed with the old problem again. Yukawa theory apparently needed drastic revision. Further, there were other theoretical difficulties, for these particles behaved in the strangest way. The new particles are directly created in nuclear interactions and so were expected to behave like the other particles which belonged to the same highly strung family. In particular, they should be so short-lived that it should hardly have been possible to detect them. It was at this time that the Japanese physicist Nishijima and also the Americans Gellman and Pais suggested that the paradox could be explained if the strange particles were produced in association like twins. Just like twins then, they feel somewhat lost when alone but behave normally when together. This idea was an immediate success. Soon, evidence was accumulated which definitely established that these indeed are created in pairs. The fledgeling theory was later expanded, placed on a somewhat sounder footing and this enabled further predictions about the existence of hitherto undiscovered particles. Nearly all such predictions have come true and in the nineteen fifties, there was feverish activity in the world's laboratories in their race to find the new particles.

Although at the beginning, cosmic rays were the only source for the production of strange particles, the man-made particle accelerators gradually took over the role. The Brookhaven cosmotron had reached 2 Bev by 1954 and was the first to produce heavy mesons and hyperons. In 1955, the Bevatron at Berkeley, California, had topped 5 Bev. At present there are several very high energy accelerators: the Brookhaven synchrotron (30 Bev), the accelerators at CERN, Geneva (also 30 Bev) and at Dubna, USSR (50 Bev). Several accelerators for still higher energies are in course of construction.

The greatest achievement as far as the production of new particles went was the creation of antiprotons by the Bevatron at Berkeley in 1956. The antiproton bears the same relation to the proton that the positron does to the electron. Thus the antiproton too had to be born along with the normal proton. The discovery of the antiproton is a landmark in the physics of elementary particles and for this achievement, the leader of the Berkeley group Segré, was awarded the Nobel Prize.

Going through the vast list of "elementary" particles, we see that starting with the electron, proton, photon and neutrino we come across the neutron, the positron, the μ-meson (two varieties), the π-meson (three varieties), the heavy meson (two families) and hyperons (several families). This list consists of some 30 odd particles and though there is a general feeling that the list is almost complete, one is never sure when a new surprise packet will come along. In fact, the expression "elementary particle" or "fundamental particle" is not as clear as it used to be since sometimes they are neither elementary nor much of particles.

One thing is clear: Just as much as the simple indivisible atom was broken down to reveal a miniature solar system, perhaps even more complex than the solar system, the investigation of the most intimate neighbourhood of fundamental particles shows a wonderland so far unsuspected. The scientists have yet only glimpsed at this new world and the ideas are still hazy. The next secret in the development of our understanding of matter and of the universe may well be hidden somewhere among these strange particles.

THIS FASCINATING UNIVERSE

Dr. George A. Dissanayake

(*Lecturer, Department of Physics*)

How many of us ever pause to consider and comprehend the vastness and the orderliness of the Universe around us ? And yet from the very earliest times the Universe has excited the thoughts of man, to attempt to explain its creation and to understand its organization. *Mythology* and *speculation* have intermingled with *observation* and *reasoning*, and it is indeed. fascinating to study the development of ideas right up to present-day cosmology.

The ancient Greeks were second to none in the mythical stories of the creation. Here is an example recounted by Robert Graves : " In the beginning Eurynome, the Goddess of All Things, rose naked from Chaos, but found nothing substantial for her feet to rest upon, and therefore divided the Sea from the Sky, dancing lonely upon its waves. She danced towards the south, and the wind set in motion behind her eemed something new and apart with which to begin a work of creation. Wheeling about, she caught hold of this north wind, rubbed it between her hands and behold ! the great serpent Ophion. Eurynome danced to warm herself, wildly and more wildly, until Ophion, grown lustful, coiled about those divine limbs and was moved to couple with her. Now the North Wind, who is also called Boreas, fertilizes; which is why mares often turn their hind-quarters to the wind and breed foals without the aid of a stallion. So Eurynome, was likewise got with child. Next, she assumed the form of a dove, brooding on the waves, and in due process of time, laid the Universal Egg. At her bidding, Ophion coiled seven times about this egg, until it hatched and split in two. Out tumbled all things that exist, her children: Sun, moon, planets, stars, the earth with its mountains and rivers, its trees, herbs and living creatures."

About 600 B.C. Thales decided that water was the original substance of creation. Two centuries later Empedocles in Sicily put forward the theory of the four elements :— earth, air, water and fire. This theory was later endorsed by the great Aristotle himself, thus ensuring the propagation of a false hypothesis for nearly two thousand years. Empedocles however realised that the moon shines by reflected light and that eclipses of the sun occur through the interposition of the moon. He asserted that light travels with a finite speed, though the speed was too great for measurement. We see here the beginnings of a rational description of cosmic events.

During the next few centuries there followed the spectacular development of Greek thought and science. Pythagoras and his followers looked for mathematical and geometrical order in the universe: from a study of the shape of the earth's shadow in eclipses of the moon they deduced the earth was a sphere; they regarded the earth as one of several planets, revolving around a central fire (which was not the Sun). Plato combined these early ideas into a single cosmology. It was the orderliness of the universe that most impressed him, and in which he saw the hand of God. This was not the Jewish God, who created the world out of nothing, but a geometer who created order out of disorder. This idea has been echoed recently by Jeans who in his book "The Mysterious Universe" suggests that "God for ever geometrizes".

Plato believed that the phenomena of the heavens greatly influenced man's mental processes : "Had we never seen the stars, and the sun, and the heaven, none of the words we have spoken about the universe would ever have been uttered. But now the sight of day and night, and the months and the revolutions of the years, have created *number*, and have given us a conception of time; and the power of enquiring about the nature of the universe; and from this source we have derived philosophy..."

Then followed Aristotle, who dominated scientific and philosophic thought for two thousand years. To him the majestic circular motions of the sun, moon and the planets were of a quality and perfection not to be found on the earth. He divided the universe or cosmos into two parts, with the orbit of the moon as the dividing line. "Things below the moon are subject to generation and decay; from the moon upwards everything is ungenerated and indestructible. The spherical earth is at the centre of the universe. In the sublunary sphere, (region below the moon), everything is composed of the four elements ; but there is a fifth element, of which the heavenly bodies are composed...... The heavens are perfectly spherical, and the upper regions are more divine than the lower.

About 250 B.C. the Greek Aristarchus had sufficient evidence to put forward the complete Copernican hypothesis, including the fact that the earth rotates on its axis once in twenty four hours. He and others of the same period even sought to calculate the size of the earth and the distances of the moon and sun,—a remarkable feat for people whose world was then limited to the Mediterranean shores and the Middle East ! They even got the right answers except for the sun's distance, where they underestimated.

Copernicus in 1543 and later Galileo established beyond doubt the Copernican Universe —first mooted vaguely by Pythagoras and his followers. Galileo sided Copernicus in demoting the earth from its central position in the cosmos, and placed the sun in the centre. He also built one of the very first telescopes and discovered Jupiter's four moons. It was these ideas that he was later forced by the Church to recant.

It was significant that the year 1642 in which Galileo died, Isaac Newton was born. To him the world of Nature was an open book. He included under one set of laws the motions of the heavenly bodies and the motions on the earth ; the force that made the apple fall was shown to reach out in the heavens, where it held the moon in its orbit and kept the planets circling round the Sun. Newton's *Principia* remains one of the supreme achievements of the human mind. His revelation of the universality of the laws of Nature enabled man to feel he was truly part of the cosmos. The heavens did not sit in judgement on him or influence his life ; comets, eclipses and falling stars were no longer to be looked upon as portents of evil. Instead all were subject to the same changeless laws.

The science of astronomy developed rapidly from this time. William Herschel made his first telescope in 1774 after 200 failures. Within seven years he discovered Uranus, the first planetary discovery since prehistoric times. He mapped the stellar region beyond the solar system and demonstrated for the first time that Newton's laws of motion, and of universal gravitation, apply outside the solar system too. He studied the vast aggregate of stars that we call our Galaxy, the *Milky Way*, and realised that it was limited in extent.

Herschel observed too that there was no lack of faint stars in other parts of the sky ; it just happened that there was a greater concentration in the direction of the Milky Way itself, with a steady falling off towards the other regions. He deduced that our galaxy was in fact a flattened cloud of myriad stars, more or less circular, and with a thickness about one fifth or one tenth of the diameter. It seemed to Herschel that our solar system was standing near the centre of this vast array of stars. But later, a twentieth century astronomer, Harlow Shapley, placed the sun well towards the outer rim of the Milky Way. The distances involved are unbelievable. Taking the yardstick of the Universe as the speed of the light by which we see it, the moon is a little over a second away, the sun about eight minutes; but the centre of the Milky Way is 25,000 years distant !

Hubble was able to prove that there were faint objects in the heavens far outside the Milky Way. These objects are now accepted as being other galaxies similar to our own. They have been given the name of *island universes*, floating as they do in the vastness of space. Light from the very nearest of them takes 150,000 years to reach us. The most remote of them yet observed are about three billion years away ; the light by which we see them was starting on its journey not very long after the earth itself was formed originally !

Are we really overawed by these stupendous distances ? At some stage or other we seem to reach a limit in our ability to visualize the enormity of numbers and things. What does it convey to us when we are told that our own Galaxy alone contains about 100 billion stars ? That this is but one out of about a billion galaxies in all lying within reach of our telescopes ?

Considering that each of these myriad stars are generally much brighter and larger than our own sun, it is expedient to ask "why is the sky so dark at night" ? The German astronomer Olbers first posed this question. The answer was found in the study of the island universes outside our galaxy : *they are all running away from us*, and in so doing they become less effective in casting the light of their suns back towards us. The further away they are, the faster are these galaxies receding from us. When this is taken into account, it is possible to show that a dark night is indeed to be expected.

This brings us to present-day cosmology. Cosmology is a happy hunting ground for conjecture ; it is so hard to be proved wrong ! Let us take as an example the modern theories of creation. The central fact is the expansion of the universe: all the distant galaxies are receding from us. And their present motions and positions are such that if we could trace them back in time we should deduce a remarkable thing, namely that all of the Universe we now observe started out from the same place at a certain instant in time, something like five billion years ago. One might say then that the mystery is solved—and some cosmologists adhere to this view. Eddington says "Philosophically the notion of an abrupt beginning to the present order of Nature is repugnant to me, as I think it must be to most..

But I see no escape from our dilemma." Some of the observations from which the expansion of the universe is deduced are made on distant galaxies that sent out light towards us over a billion years ago. What we see today is what those galaxies were doing while the earth was still a red-hot sphere of molten matter. Even so we cannot (as yet) see far enough out in space and time to take us right back to the presumed moment of creation. It remains possible therefore that the Universe has not always been expanding. Perhaps it is pulsating? But the most fascinating conjecture of the twentieth century cosmologists is the "perfect cosmological principle".

This new principle (sometimes referred to as the steady-state theory) asserts that we, on this earth at this moment, must not regard ourselves as privileged either in space or in time. It asserts that the cosmos would, in general, look just the same to any other observer no matter whether he be located in some distant galaxy, and whether he be ages in time before or after us. It proclaims a belief in the *uniformity* of Nature. If this is a first premise, then how can we reconcile it with the observation that the other galaxies are forever moving further apart? Surely this must mean that the Universe as a whole must look less crowded to some other observer in the distant future? "No," says the perfect cosmologist, "it shall not be," and he resolves the contradiction by asserting that new matter is created from the void to replace that which is constantly flowing away. This process of *continuous creation* is a strong favourite in the cosmological stakes. It has the added advantage of being undetectable, as the rate at which new atoms need to be created to preserve the *status quo* is incredibly small. (Hoyle gives it as about one atom per year in a volume equal to St. Paul's Cathedral, London).

Some cosmologists emphasize how *subjective* and *personal* our knowledge is : '..the external world has no real existence for us beyond the image reflected within ourselves through the medium of the senses," (Humboldt). Eddington was so convinced of this notion that he claimed that the quantitative aspects of the universe could be deduced by the human mind from an awareness of qualitative features only. He believed that he could calculate the total number of atoms in the whole universe merely from a knowledge that atoms and space exist. In fact he seemed to get the same answer as those who laboriously scanned the heavens and counted the stars !

Mark Twain in "Life on the Mississippi" concludes : "There is something fascinating about science. One gets such wholesale returns of conjecture out of such trifling investment of fact." Perhaps this is the type of scepticism that might be aroused by present-day cosmological conjecture? Bernard de Fontenelle in 1688 gave a similar warning : "In Love and Mathematics, People reason alike : Allow ever so little to a Lover, yet presently you must grant him more ; nay more and more, which will at last go a great way. In like manner, grant but a Mathematician one little Principle, be immediately draws a consequence from it, to which you must necessarily assent; and from this consequence another, till he leads you so far (whether you will or no) that you have much ado to believe him. These two sorts of People, Lovers and Mathematicians, will always take more than you give them."

Dear Mr. Editor,

Your request for an article rather knocked me off balance—gave me a sort of Inferiority Complex I did not possess before. This was, perhaps, partly caused by your "Mathematical Society" letter-head. I was so wretchedly bad at Maths: of even the simplest sort that I thought it would be a good idea to get my tutor to do my impositions at home—it didn't work. The old boy was too much of a gentleman. I was rather like the little boy who was asked by his teacher to stop using his fingers when adding, "Put your hands in your trouser pockets, Johnny, before I ask you the next question, now how much is seven and three ?" The poor little chap got so flurried that his answer exceed his fingers.

As for the Faculty of Science, I know that "Science" means "Knowledge," and "Faculy" is "aptitude for any special kind of action," but beyond this my knowledge fails me. However, in other ways, I feel slightly superior to you Varsity chaps for I've been to two Universities much older than yours—they are Oxford and Cambridge—if you'd like to know. I was at Oxford (the town of) and visited Cambridge on a fine day with a bossomed Browny Box, the result of my efforts left nothing to be desired. I therefore have every right to talk of "The days when I was at Oxford" or "Since I was at Cambridge . . . . . ."

I have a vague recollection of the distant, school-going past at Royal. I attended Science classes which had to do with Chemistry—H_2O *and all that sort of complicated stuff. We used to be given little glass receptacles which I was made to understand were called Test Tubes because you put various liquids and crystals into the frail little things and then heated them till you got something quite different. You were then told to note-down your results in an exercise book—which I* *seldom did because my tubes always went bust and I was chased out of class or made to stand in the corner of the stinking gas ridden room.*

The Science of flinging Tomatoes and rotten eggs, and the art of directing them accurately at the target was unfortunately not known in my time. I envy the present generation, it must be great fun gaining one's point in this nourishing manner. We knew nothing about Majorities and Minorities either,—it was rather a backward age I grew up in, and if we wanted to take off our trousers we did, it never crossed our minds for one little moment that we should permit someone else to do it for us. If an individual of the older (that's my) generation, handn't the courage to tell a person what he thought of him he would write him a stinker, and mark it Confidential; it didn't enter our heads, and fools that we were, that sticking with spare spittle ammunition, a crippling-below-the-belt, slogan on a piece of cardboard nailed to a broomstick and taking it in procession was a far more honest and open way gaining one's point.

Apart from what I've just said, I sincerely feel in my creaking bones that you all, the future rulers of this lovely little nation will come up to scratch and make it a paradise for all those who live within its boundaries. The day of the common man has come to stay, which is as it should be. No slavery, no "I'm better than you," "who the hell is he" sort of nonsense. For heaven's sake let all communities, castes and religions go hand in hand and work as one, so that every individual can find his little place in the sun.

Yours Sincerely,
Bevis Bawa.

RELATIVISTIC ROMANCE

V. Joseph

(*Lecturer, Department of Mathematics, University of Ceylon*)

One starry night little Christine sat at her desk doing her homework. She hated mathematics and could not work a simple problem on moving trains. She went out into the garden and called out for Nimal the big college boy next door. Nimal walked up to the fence with an expectant look. " If two trains A and B move in the same direction with speeds 40 m.p.h. and 30 m.p.h. what is the speed of A relative to B ? " beamed Christine over the fence. " Well, that's too easy; the answer is ten " replied Nimal. " How do you do that ? " inquired Christine. " Simple, you subtract one from the other " declared Nimal as he scribbled the figures 40-30 = 10 on Christine's exercise book. Christine watched the jugglery with a rather puzzled look on her face. "That's what they all do anyway," added Nimal, trying to put the little girl's mind at ease. Unable to grasp the problem with her perplexed mind, the little girl thought poorly of her own talents and looked admiringly into Nimal's eyes. She thanked him for the help and ran into the house. Nimal felt that girls were not born to be mathematicians after all, and walked back to his house after gazing at the night sky.

Some years later Nimal graduated with honours in Mathematics. One day he opened a book on Einstein's Theory of Relativity in the University Library. He read that if two trains A and B move in the same direction with speeds v and u then the speed of A relative to B is $(v\text{-}u)$ $(1\text{-}uv/cc)$ and not $v\text{-}u$ as he had taught Christine (In the formula c is the speed of light). This came as a rude shock to him. It was Nimal and not Christine who was now looking perplexed ! His spirit was terribly shaken up !

Nimal spent restless nights trying to resolve the difficulty. He resurrected his spirit and sent it hither and thither in search of the truth. His spirit took leave of his body and made strange adventures. It hovered about train A for some time, then leaped and clung onto train B, and sometimes found itself on the station platform watching the trains rush by.

As the restless days passed by Nimal perceived that every spirit is conscious of the flow of an independent time in its own environment. He realized that it is only by peopling the moving trains with *different* spirits, one in each, and one on the platform, that we can get into grips with the outer world of reality. Relativity which implies plurality, provides the mathematical coordination for the experiences of different spirits. *A single spirit on the platform is incapable of contemplating the relative motion of the two trains in its entirety.* Nimal was reminded of the poet's warning :

> Ah ! But for man the microcosmic fool
> Who so often would love to see himself whole !

Einstein had sensed this simple truth and used this notion admirably in the formulation of his Theory of Relativity. It is simple, beautiful and remarkably child-like :—

A child on a moving train tells the father that the platform is moving. If the father puts the child on the platform, the child will say that the train is moving. Here the child expresses its own true condition—pure naivete, but not so the father whose spirit is weighted down by the mundane platform and convention. The father will solemnly declare that it is the train that is moving even when he is on the train. In the pure naivete of the child whose spirit is still free and unfettered contemplation *in* the environment of any train or platform is possible, and with such contemplation there goes Einstein's great insight.

In his college days Nimal was spiritually egocentric for he had tried to comprehend the relative motion of the trains A and B by spreading *only* his spirit on the platform. He had thus arrived at the result 40-30 = 10 in the wake of his own ruffled spirit, which only puzzled poor little Christine. Had Nimal in those youthful days taken the little girl resolutely by her hand and led her on the calm royal highways of the spirits, which are many and varied indeed, Christine the living creature would probably have had a better feeling of the material world.

Some years later the handsome young man Nimal met the gracious lady Christine at a party and convinced her that the world would be a better place if there were more spirits working for the great transformation of the material world. They were soon engaged to be married.

The wedding cake was a large mansion with many windows, symbolizing the wide world with its conscious beings. The marriage ceremony was performed according to the relativistic rites of evolutionary humanism :

Our little frames of reference
Have their day.
They have their day
And cease to be.
They are but........
Broken Lights of Thee.
And Thou, O ! Nature,
Art more than they.

Thanks to Relativity, Nimal and Christine lived happily thereafter in complete harmony with Nature.

MATHEMATICS IN ITS PROCESS OF DEVELOPMENT

S. Balasubramaniam, B.Sc. (General), Final Year

The impact of mathematics on world thought has been tremendous. Besides contributing to our civilisation in the more obvious areas of engineering, architecture, and the physical sciences, it has shaped philosophic movements, founded and challenged theological doctrines, and had its influence felt in all branches of human endeavour from politics to music.

We owe the beginnings of our philosophy, science and mathematics to Greece. Although some arithmetic and geometry was known to the ancient Egyptians and Babylonians, they were mostly in the form of rules of thumb. Mathematics as a form of deductive reasoning from general premises originates from Pythagoras. He discovered the importance of numerical relationships and was one of the main forces that shaped th philosophy of Plato.

Mathematics has often been viewed, and is still been looked upon by some nonmathematicians today, as a body of knowledge that is certain and exact, the symbol of absolute truth. Moreover, it was obtained by intellectual activity and had, therefore, the halo of the "ideal" with which the empirical observation could not compete.

The Greeks were intrigued by abstract concepts because these appeared to be perfect and permanent, while physical objects were perishable and corruptible. In an ever changing world, that is in a continuous state of flux and where therefore, no knowledge can be static, it is not surprising that mathematics, with its claim to eternal truth, stood forth as the proof of the godhead.

Theology has its roots in the absolute and static truth of mathematics. Since Pythagoras, and especially since Plato, mathematics supplied the proof for the concept of eternal and exact truth revealed to the intellect but not to the senses. The Pythagorean-Platonic idea that mathematics is the essence of reality provided a perfect instrument for the Christian concept of a rationally designed universe.

To solve many early puzzles of mathematics, people followed the principles of Euclid. Euclidean geometry starts with axioms deemed to be self-evident and, by a process of deductive reasoning, arrives at theorems which are not so evident. This technique of thinking was employed by most philosophers in the Middle Ages and many later ones. One of the major differences between classical culture and our present civilization is that the Greeks stressed deductive reasoning from self-evident axioms while our modern scientific world is obtained inductively from observation. The reason for this difference in outlook was the classical Greeks contempt for work and disdain even for commercial activit. Under those circumstances experience could teach them little and empirical science could not develop.

The influence of mathematics on world thought can be divided into two periods. The classical epoch, when it was closely allied with theology, which needed something like the multiplication table as a symbol of absolute truth ; and the modern era from 17th century onwards when it entered into partnership with science and, culminating in the theory of relativity, demolished the very concept of the absolute truth it so powerfully supported in an earlier age.

Pythagoras, however, still scores victories. His main thesis that phenomena should be interpreted in terms of quantitative relationships dominates modern science. The theory of periodicities he propounded in relation to music is still triumphing in the philosophy of quantum mechanics. Copernicus reduced the earth from its lofty position as the centre of the universe to a little whirling speck of mud. The mathematical accomplishment of the 16th and 17th centuries have changed the medieval outlook and created new trends in the sciences, philosophy, religion and literature.

Philosophy has two main functions ; one is scientific, the interpretation of nature, the other political : a guide for conduct. With Descartes, philosophy and theology parted company. He thought that a valid body of philosophy could only be based on the principles of geometry, because only geometers have been able to reason clearly and arrive at indubitable truth. For the creator of coordinate geometry the universe was a giant, mathematically designed machine. The fact that we appear to perceive events in a sequence of cause and effect was due only to the limitations in our sensory apparatus. Mathematical relationships are pre-existing ; therefore, all events are determined by logical consequences, as the properties of geometric figures. His reasoning mirrored the principles of Euclid, embodying in his philo ophy the apex of casuality.

The history of modern science, starting with Galileo, consists of the steady elimination of supernatural forces and the gradual reduction of natural phenomena to quantitative relationships. Philosophers throughout history can generally be divided into two camps: The ones mainly mathematically oriented; and the other whose preferred mode of investigation was empirical. Pythagoras, Plato, Descartes, Spinoza, Leibniz and Kant belong to the first group; while Democritus, Aristotle, and especially Locke, Hume and the modernempiricists belong to the second group. All the founders of modern science, Galileo, Descartes, Huyghens and Newton, used mathematical, deductive reasoning, even though they were careful to check it out with observed data. They very well realised individual facts have no great importance: the value lies in the theory uniting them. This realisation started a long and snowballing trend to embody the laws of nature on mathematical formulae. That mathematics can lead to derivation of universe laws was demonstrated by Newton, who arrived at the laws of gravitation through the creation of calculus.

Leibniz, the other inventor of calculus, wielded tremendous influence on philosophy. By applying symbols to the fundamental operations of reasoning, he became the founder of symbolic logic, which was in the twentieth century perfected by Whitehead and Russel, who set out to derive mathematics from logic and thus succeeded in rescuing mathematics from much contradiction. Mathematical logic is extremely powerful and offers solutions to problems which would have baffled earlier logicians.

Soon after Newton's law of gravitation displayed a mathematically designed, machine-like universe, mechanistic principles became apparent in other areas of science. In biology for example, Harvey discovered the circulation of blood and the heart's pump-like action. The quantitative approach invaded all fields and phenomena, whether natural mental or social, raising mathematics to the position of queen of the sciences.

This mechanistic view was the cornerstone of philosophy of the enlightenment. The materialistic view culminated in determinism. According to Laplace the heavens obeyed rigid mathematical laws, and the future of the universe was clearly predictable from the past. If all material motion is determined by physical laws, then through parallelism, mental events must also be determinate. The triumphant march of science more and more exalted the materialistic realm of nature and overlooked the fact that it was the genius of man that devised the mathematical tools which penetrated to the core of phenomena.

Mathematics is nothing concrete, merely an artificial projection of our minds. Its greatest contribution to philosophy is that it imposes harmony and order on the matrix of nature, that would otherwise seem disorderly and even anarchic. The simplicity and design in the structure of Universe that so impressed the founders of modern science appeared with 19th and 20th centuries, to crumble with emergence of statistics and probabilities. The effectiveness and reliability of the statistical method in predicting the outcome of events which baffled the proponents of classical mechanics posed a serious challenge to the philosophy of determinism. In any consideration, from the process of biological heredity to the flipping of a corn, the mathematical laws of probability, based on the caprices of naked chance, accurately predict the average effect of disorderly occurrences. The probabilistic interpretation of phenomena is one of the most powerful forces that are shaping modern philosophy.

Though it eventually set the stage for materialism, the idea of a mathematically designed and ordered universe was always the strongest argument for existence of God and thus formed the backbone of an unshakable and absolute body of ethics. If man is an accidental freak of nature, there seems to be little more left on the stage of life drama than the pursuit of whatever the moment can offer. It is striking how far mathematical developments determined the attitude of men towards nature, society, and the meaning of life.

The effect of an entirely mathematical creation on philosophy can nowhere be better illustrated than in the case of theory of relativity. Since for a long time mathematics was the temple of absolute, truth it may seem strange that it was mathematical reasoning which removed the concept of static truth from its lofty position in the minds of men. Einstein's equations have demonstrated the relativity of time and motion. The relativity of time upsets one of the fundamental assumptions of philosophy of the science. If time and motion are relative, the relationship of cause and effect is exposed as mere prejudice of our sense organs. For an observer in a state of motion different from ours, an event we would call the effect could very well appear before the cause.

If the order of events is reversed in time for some observers it may appear that a person's actions are shaping his decisions, instead of the reverse. This, incvidently may perfectly agree with some modern theories in psychology. Classical physics was based on the fact that given the state and velocity of every material body, the entire history of the universe can be calculated for all time. Only laws of mathematical probability can establish some order among the infinite uncertainties of capricious universe. Quantum mechanics not only agrees with uncertainty principle but asserts that an electron does not even traverse its path continuously in space. This is analogous to an airplane appearing over different cities without traversing the distance between them. The notion of the continuity of motion is thus reduced to a mere illusion of our sensory apparatus.

Thus the world of mathematical abstractions cannot fail to shape philosophical thinking. Ever since the 17th century, scientific accomplishments have burdened philosophy with materialism Modern physics, however, made matter less material. With mass-energy equivalence principle, events have replaced particles as the ultimate reality in physics: and quantum theory has pulled the rug from under the entire edifice of materialistic philosophy.

The most important characteristic of modern thought is that it uses freely the deductive methods of mathematics, but tests the conclusions experimentally. The real world appears to be nothing but a scheme, expressed in the abstract language of mathematics, that defines—as empirical results prove—the fundamental phenomena more accurately than man's feeble attempts to peer through the clouded windows of his senses.

One fellow says his new phone number is easy to remember. You just double his age, multiply by his street address, subtract from his car number—and call information.

A patient who was thoroughly examined by a surgeon who prescribed a simple operation to relieve his ailment. When the surgeon asked if he wanted the operation performed immediately, this patient replied, "How will this affect my hobby ?"

Puzzled, the doctor inquired, "What is your hobby ?" "Saving money," was the reply.

When school children in a town went to a hospital for a medical check up, the X-ray technician each day would instruct a different group to strip to the waist, line up at the door to the X-ray room and hold out their X-ray cards—and each day some one would hold out the wrong card or go to the wrong door. One day after days of this agonising ritual, the technician shouted, in a blaze of frustration, "Every day I tell you fellows the same thing ! Don't you ever learn ?"

A mathematics teacher, specializing in geometry, was heard to mutter, "I love my wife, but oh, Euclid !"

An undergraduate once pleaded to a lecturer, "to forgive and forget" and the lecturer said, "I can forgive but if you ask me to forget, you ask me to give up experience."

DEFINITION OF NUMBER AND RUSSEL'S PARADOX

By

(A. A. A. E. H. M. M. N. R. S. W.)

Arithmetic is that branch of Mathematics which is used by almost everyone in every walk of life. It deals with number and its properties. By number, here we mean the positive real number. The set of all positive real numbers has developed from the set of positive integers. The concept of the positive number must have surely been born in the mind of the human being when he learned to make use of his power of reasoning and yet even in this advanced stage in the development of the human being, the definition of number has not been put on a firm footing.

Mathematicians in the early stages of the development of the subject took number to be one of the most fundamental ideas not requiring definition. They took it for granted and worked out results which were verified practically. They were only interested in the applications of the results obtained in Arithmetic and did not probe the foundations. This attitude continued and Arithmetic expanded its field of activity and grew in stature, and yet only a few made any worthwhile contribution on this aspect of the subject. One of these was Peano. His definition of the natural number was embodied in the following five postulates.

(1) 1 (one) is a number.

(2) For every number, there is one and only one number called its Successor.

(3) Two distinct numbers do not have the same successor.

(4) There is no number which has one as its successor.

(5) If a set of numbers contains the number one and for every number it contains it also contains its successor, then it contains all the natural numbers.

Here Peano based his definition on 'one' and 'successor' which he took to be self-evident, undefined elements. I have made special mention of this as postulate five has fairly important applications in Mathematics. All students of Mathematics would notice that this is the basis for the 'proof by induction' method they use.

There have been many other useful contributions made on this subject but cannot be included here lest we may stray away from the scope of the title. It would however be pertinent to mention that more recent attempts on the definition have been based on Logic. We shall now proceed to the modern definition of number and the difficulties encountered here. Number is no longer taken to be the most fundamental idea and the necessity for a definition has been universally accepted. A definition of anything requires concepts which are more fundamental. For the definition of number we start with the idea of 'Sets.' Sets are collections of objects or elements.

Definition :— 'A Natural Number is said to be the set of equivalent sets.' Two sets are said to be equivalent if there is one-one correspondence between them. Consider two sets A and B. They are said to be in one-one correspondence if and only if for every element in A there is an unique element in B corresponding to it and vice-versa. For example consider the set P≡(Apple, Boy, Cat, Dog, Egg) and the set Q≡(D, A, C, B, E). If we define our correspondence between the elements of the sets in the following manner : An element of P corresponds with an element of Q if and only if the first letter in the element of P considered is the same as the element of Q considered. Then we see that the correspondence is one-one. If however instead of P we had the set R≡(Apple, Boy, Cat, Dog, Deer) and the rule of correspondence between elements of R and Q is the same as above the correspondence between R and Q is not one-one.

Though at first glance it may seem that this definition of number is far fetched, careful consideration shows it to be quite the contrary. It is in fact quite closely related to the cause for the existence of this concept of number. An example will illustrate this fact. Consider a farmer who is ignorant of the existence of natural numbers. We shall suppose that he has ten cows. If he takes them out to the fields for feeding, when he brought them back he would like to check whether he has brought back every cow. Being unable to use the number system what he would do would be to send them into their enclosure one by one and as each one passes he would bend a finger. If as the last one enters all his fingers are bent then he has brought in all cows, for he knows that there is a correspondence between his fingers and the cows he possesses. This also illustrates the fact that sets are more fundamental in nature than number. For the farmer, without resorting to the use of numbers, works with two sets, one of cows and the other of fingers. He actually has set up a one-one correspondence between these sets. He works with two equivalent sets. As far as the counting was concerned he could have used any set equivalent to the set of cows instead of the set of fingers. As we know now, what is common to all these sets is the number ten. Hence the definition.

The definition of number seems quite satisfactory and does not cause any difficulties. But a careful study of the theory of sets shows that there is a major difficulty.

Consider the set A≡(Colombo, Peradeniya). Does set A belong to itself ? Set A is neither Colombo nor Peradeniya. Hence set A does not belong to itself.

Consider the set B≡set of all Ideas. Does set B belong to itself ? Set B is itself an idea. Hence set B belongs to itself.

Therefore we see that there are two types of sets. One where a set belongs to itself and the other where it does not.

Now consider the set C≡set of all sets which do not belong to themselves.

Does C belong to itself ?

Suppose C belongs to itself, then from the composition of C it follows that it does not belong to itself.

Suppose C does not belong to itself, then it follows that C belongs to itself which give us self-contradictory statements. This is called Russel's paradox.

The definition of number depends on the properties of sets and hence cannot be said to be on a firm footing, since the theory of sets yield some contradictory results.

MATHEMATICAL AIDS FOR CLIMATOLOGICAL RESEARCH IN CEYLON

GEORGE THAMBYAHPILLAY Ph.D. (Cantab.),
(*Department of Geography, University of Ceylon*)

INTRODUCTION

In the field of meteorological science, practically in every phase, the use of mathematical aids has become a *sine qua non*. In the process of plotting the daily synoptic charts, in the determination accurately of weather parameters, in the prediction of weather patterns and in all related investigations, the mathematical or numerical factor looms dominant. "Numerical weather forecasting" has come to stay and is a basic activity of all modern meteorological centres. The use of complicated automatic computers to work out the detailed parameter relationships and even to transfer such numerical derivatives onto weather charts automatically, is becoming more the common feature. Even at the Colombo Observatory in Ceylon, mathematicians and physicists turned meteorologists, are daily involved in transferring onto synoptic charts, the codified information relayed to ground receiving sets, by miniature radio transmitters that are carried aloft to over 50,000 feet as components of radio sonde balloons. The operation of International Airlines through Ratmalana and Katunayake, is vitally dependant upon adequately maintained numerically-based weather plotting, in conformity with international standards.

THE MEAN AS A CLIMATOLOGIC STATISTIC

$$\bar{a} = \frac{1}{n} \sum_{i=1}^{i=n} a_i$$

In the climatological field, however, the use of advanced mathematical aids has been of recent adoption. It has become an unfortunate habit that climatologists tend to be too conscious of the overall sufficiency of the *arithmetic mean*. Often it is, that even in that particular branch, designated agro-climatology, the arithmetic mean computed from varying series of data, is accepted with little or no reserve. To the agro-climatologist the adoption of this statistic becomes of vital significance, because on the vailidity of this statistic would depend the success or failure of crops. To lend real meaning to the dangers of adopting such a simple statistic, it may be pointed out, that in Ceylon all mean values of the climatological elements such as temperature, humidity and rainfall, are computed from data covering the *standard period* 1911-1940. It is also of significance that this 30-year period was adopted purely from the convenience of administrative expediency, since observations in Ceylon on an 'international' basis commenced in 1907. The inadequacy and the real danger of the adoption of this data-series for computing the mean has already been pointed out (Thambyahpillay, 1960 b). In the thirties, a geographer turned climatologist (Crowe, 1933) pointed the way to a better derivative of an 'average statistic' for agro-climatological usage, by the adoption of the *statistical median* and its ancillary devises—the quartiles, the octiles, the deciles and the inter-quartile range. In the context of the climate of Ceylon, with special reference to semi-arid and sub-humid moisture zones, the supremacy of using the median and its attributes, over hitherto used mathematical derivates, was demonstrated in a recent paper (Thambyahpillay 1960 b).

In the same context, adoption of the mean and the median, for deriving by mathematical computation, the very significant aspects of the rainfall of Ceylon, namely variability and reliability which, even more so is of vital concern to the agro-climatologist, does bring out some remarkable features (Thambyahpillay, 1960 b). In the same paper, it was also demonstrated how other mathematically-derived 'statistics,' *viz*, mean variability or mean deviation, relative variability, standard deviation, coefficient of variation, *inter alia*—are of real significance to a proper and better understanding of the agro-climatology of this island. In particular, wherever it was necessary to adopt short-period data in correlation with reliable long-period data, these 'statistics' proved invaluable. Mathematical formulae also become of value in the process of 'adjustment' of the short-period data, especially of those recently established meteorological stations, where observations of other agro-climatological attributes such as evaporation, evapotranspiration are maintained.

NEW TECHNIQUES FOR DEMONSTRATING CLIMATIC CHANGES AND FLUCTUATION—PATTERNS

In investigations into possible evidence for climatic changes and climatic fluctuations, the usually adopted technique of comparing simply-derived mean values for specific periods, has recently come to be discarded. Instead, two new devices have come into wide usage, in view of their potentialities in bringing to light, hidden periodicities and secular trends. The moving averages curve (overlapping means or running means curve) and the residual mass curve (cumulative deviation curve) have been applied to long-period and reliable data, pertaining to areas ranging from the tropics to the polar zones, and hitherto unsuspected periodicities and trends have been brought into evidence. These devices, though in effect simple to derive mathematically, gain real significance when rendered into graphical forms. They help not only to 'reveal' otherwise masked "trends," "cycles" and changes in the climate of any locality or region but also help in the correlation of such patterns between stations and between regions. This has eventually brought into focus, a most noteworthy finding, namely that such seemingly isolated patterns are strongly interrelated even with the general circulation patterns over the earth. The application of these mathematical aids to data derived from meteorological and rain-guage stations in Ceylon (Thambyahpillay, 1958 a, 1958 b and 1959) have proved of immense significance. All previous attempts that were made in investigating this problem of 'climatic change in Ceylon' proved fruitless, because the only technique adopted was the simple computation of comparative mean values. The author's own investigations have demonstrated most clearly that not only have the data revealed actual secular trends but also that such 'trends' are strongly correlated to similar trend-periodicities, in the tropics (Thambyahpillay, 1960 a). Thus, the fluctuation patterns of the river Nile regimes, and the variations in the levels of the lakes Victoria and Nyanza exhibit remarkable correlation, with the trend-periodicities and patterns of the rainfall climate of Ceylon (Thambyahpillay, 1958 a). Yet another investigation by the author has revealed that sunspot cycles (23-year Hale cycle) also exhibit remarkable correlative trends with the annual rainfall climate of Ceylon and with the aforementioned river Nile and lake levels of Victoria and Nyanza (Thambyapillay, 1960 a).

The greater possibilities of the use of other mathematically-derivable expressions for adoption in fluctuation investigations, using harmonic analysis have already been demonstrated in many instances. Thus, for example, the Schuster Periodogram (Brooks and Carruthers, 1953), though laborious in preparation, is an invaluable aid to provide more exactitude to probable 'periodicities' demonstrated by the earlier mentioned devices, such as the moving averages curves and residual mass graphs. The 'chain analysis' technique, again has the very special advantage, wherein it renders possible the reading of the history of the periodicity on the basis of the revealed amplitude and phase diagram. The residual mass curve, reveals not only the dates of 'phase change' viz. from a 'wet' phase to a 'dry' phase or from a 'warm' phase to a 'cool' phase and *vice versa*, but in its 'kinks' reveals also any significant, though incidental anomalies during any specifically discernible phase-trend. In combination with the chain analysis, the residual mass curve would serve to highlight the demonstrable potentialities of periodicity investigations. The chain analysis is of even more significance, because even if the discernible periodicity persists only in respect of part of the data-series under consideration or even if such a periodicity changes amplitude and phase, such facts become revealed as progressive changes (somewhat smoothed, though) of the value of the amplitude or the angle of slope of the phase curve. Even if the data-series are interrupted and if any disturbed periodic time series are to be revealed, then it is possible to demonstrate them by the construction of the more mathematically involved construction of the correlation periodogram or what has now been designated as the "correlogram."

The already revealed periodicity patterns and trends of the climate of Ceylon, on the basis of the author's own researches, are now in the process of being subjected to analysis by the periodogram and correlogram methods (harmonic analysis) and the results would appear as a research paper.

CORRELATION COEFFICIENTS

The reference has already been made in this paper, to the demonstrability of 'correlation patterns' on the basis of simple mathematically-derivable techniques. Such graphically-expressed correlations must be supported by quantitative or numerical expressions. Thus, for example, it was pointed out earlier in this paper, that a research investigation (Thambyahpillay, 1960 a) has shown the strong correlative trends between the sunspot (Hale) cycles and the approximate 23-year rainfall periodicities of the annual and seasonal regimes of Colombo in particular and of Ceylon in general. The attempt at a quantitative expression of this qualitatively-significant phenomenon, was made by the author (Thambyahpillay, 1958 a), by the technique of computing the *correlation coefficients* between the data of sunspot numbers (Wolfer series) and the rainfall climate of Ceylon on a regional basis. It was seen that most of the 'rainfall regions' (with the exception of one) indicated negative correlation coefficients with the sunspot numbers. However, individual climatological stations in the island showed remarkable positive correlation coefficients with sunspot numbers.

At this stage it would be relevent to demonstrate clearly yet briefly, the significance of the expressions, positive and negative correlation, in the context of the technique of deriving the mathematical expression—the correlation coefficient.

When two variables (e.g., climatical variables such as temperature, rainfall, sunspots, lake levels, river regimes etc.) tend to exhibit some apparent relationship (numerically or graphically) then the reality and validity of such a relationship can be determined quantitatively by the technique of computing the correlation coefficient (C.C.). Such a relationship between two variables may either be direct (positive) or indirect (negative). The expressions, positive C.C. or negative C.C. may then be used appropriately.

If two variables X and Y are to be analysed for a possible C.C. relationship, then their series may be compared in pairs by adopting the deviations, x_i and y_i, where,

$$x_1 = X_1 - X \quad \text{and} \quad y_1 = Y_1 - Y$$

Here,

X and Y represent the arithmetic means of the variables X and Y, respectively;

X_1 and Y_1 represent the absolute values of the data-series, pertaining to the two variables, X and Y, respectively;

x_1 and y_1 represent the deviation values of the data-series in respect of the two variables X and Y.

Direct comparison of the absolute values of the pairs of the series is not possible, because in effect, the arithmetic means of the two variables X and Y may not be equal. This is so since the numerical components of the respective series may not be directly related, as for example if C. C. is to be determined in respect of the annual rainfall of Ceylon and the sunspot numbers or between the annual temperature at Colombo and the annual rainfall at Anuradhapura.

The formula for determining the Correlation Coefficient may be one of two expressions. Thus :—

Either

$$r_{xy} = \frac{\left(\frac{1}{n}\right) \sum_{i=1}^{i=n} x_i y_i}{\sqrt{\left[\frac{(\Sigma x^2)}{n}\right.} \sqrt{\left.\frac{(\Sigma y^2)}{n}\right]}}$$

$$= \frac{\Sigma x_i y_i}{\sqrt{\Sigma x_i^2} \sqrt{\Sigma y_i^2}}$$

Or

$$r_{xy} = \frac{1}{n} \frac{\Sigma x_i \, y_i}{\sigma x \, \sigma y}$$

$$\text{since} \quad \sigma x = \sqrt{\frac{\Sigma x^2}{n}} \qquad \text{and} \quad \sigma y = \sqrt{\frac{\Sigma y^2}{n}}$$

where $\sigma x \; \sigma y$ = standard deviations of the respective variables x and y.

r_{xy} = Correlation Coefficient (C.C.).

If the relationship between the variables X and Y is directly proportional, then the C.C. has the expression :—

$$r_{xy} = +1.$$

On the other hand, if the relationship between the variables X and Y is indirectly proportional, then the C.C. has the expression :—

$$r_{xy} = -1.$$

If however, there is absolutely no relationship whatsoever, between the variables X and Y, then obviously the C.C. would be expressed thus :—

$$r_{xy} = 0.$$

In practice, it is usual to observe a C.C. greater or less than zero, which in effect may result by pure chance and especially so, when the number of observations are small (i.e., small data-series). Thus, it is clear that the more pairs that are used in the computation, the greater is the validity and the significance that may be attributed to the resulting C.C. It is necessary therefore to obtain longer data-series for such comparative studies so as to determine any useful C.C.

A further check is available in validating the significance of any resulting C.C., by the adoption of the factor of the probable error (F). Thus the expression :—

$$F = 0.6745 \; \frac{1 - r^2 \; xy}{\sqrt{n}} .$$

The smaller F is, in comparison with the computed C.C., the more real and valid is the ensuing relationship between the two variables X and Y. However, opinions vary over the adoption of the numerical ratio of the C.C. to the probable error. It has been argued that, "unless it is confirmed by physical reasoning or other independent evidence, a correlation coefficient should not be accepted as significant, unless it (C.C.,) exceeds three times its probable error, in which case the odds in favour of significance are 20 to 1........; an isolated correlation coefficient should not be accepted unless it (C.C.,) is four or five times its probable error" (Meteorological Glossary, 1939). Yet others (Conrad and Pollack, 1950 and Landsberg, 1943) even demand a more stringent ratio viz., the C.C. be six times the probable error (F). Thus :—

$$r_{xy} = 6 \text{ F}.$$

In the context, of this paper, where the demonstration for probable C.C. is being made between the annual rainfall of relative 'rainfall regions' in Ceylon, the probable error is adopted on a three times ratio basis. Thus :—

$$r_{xy} = 3 \text{ F}.$$

This is being adopted in view of the long data-series (1871-1950) of eighty years and because of the known physical relationship of the factors involved.

However, before actually calculating a C.C. the attempt was first made to determine possible C.C. by the construction of graphs. The principle adopted for this graphical determination of possible relationships, is that by using pairs of variables, regression lines may be drawn on simple scatter diagrams (Fig. 2). When two regression lines drawn through the corresponding deviation plots intersect at right angles, it would then be safe to assume that no relationship whatsoever exists and the expression of the correlation coefficient is accepted to be :—

$$r_{xy} = 0.$$

Whenever such intersections occurred, calculation of the C.C. was naturally not undertaken. Since it is also to be accepted, that in view of the known graphical relationship that, angles between regression lines form inverse measures of the correlation between two variables (Brooks and Carruthers., *op.cit.*,), exact proportional relationship was assumed only when regression lines coincided.

REGIONAL RAINFALL CORRELATION IN CEYLON

On the basis of rainfall data derived from ob·ervations maintained at over 500 rain-gauge stations for varying periods but appropriately 'adjusted' to conform to the reliably maintained long period records of forty-four stations (Table 1), the island was divided into 'rainfall regions' (Figure 1) using a number of criteria. The attempt was then made to graphically determine the existence of possible relationship between the annual rainfall of these rainfall regions (Fig. 2). Only when regression lines on the graphs showed fairly small angles at their respective intersections was the computation, of the C.C. undertaken. The results have been tabulated in Table II.

TABLE I : Rainfall Stations with long-period and reliable data selected for the demarcation of Rainfall Regions shown in Figure 1.

Station	Mean Annual Rainfall (1811—1950) inches	Rainfall Region
Allai	71.1	IV
Ambanpitiya	103.7	V
Anningkande	139.8	I
Anuradhapura	55.6	VII

Station	Mean Annual Rainfall (1811—1950) inches	Rainfall Region
Badulla	72.1	III
Batticaloa	65.9	IV
Chadayantalavai	66.5	IV
Colombo (Fort)	81.1	V
Dambulla	63.3	VI
Dandeniya	75.1	II
Diwulana	71.8	IV
Galle	94.4	II
Gourakelle	92.6	III
Hakgala	94.6	III
Hali Ela	108.2	II
Hambantota	40.5	IX
Horakele	68.0	V
Jaffna	51.6	VIII
Kalutara	105.0	V
Kandy	84.1	VI
Kantalai	70.4	IV
Kekanadure	71.3	II
Kurunegala	83.2	VI
Labugama	161.5	V
Magallewewa	58.5	II
Mannar	89.5	VIII
Mariawatte	103.6	VI
Matale	79.8	VI
Negombo	72.5	V
New Forest	110.9	VI
Norwood	122.4	I
Nuwara Eliya	89.5	I
Padupola	214.9	I
Pelmadulla	129.8	I
Puttalam	44.2	VIII
Ratnapura	152.8	I
Rukam	75.8	IV
Sakamam	63.4	IV
Sandringham	83.2	I
St. Martin's	170.8	III
Tissamaharama	40.0	IX
Trincomalee	66.0	IV
Udahena	108.1	III
Udukiriwila	61.8	IX

TABLE II : Correlation Coefficients of annual rainfall computed for bringing out interrelation between the nine Rainfall Regions of Ceylon (Figure 1).

The upper value represents the correlation coefficient (C.C.) and the lower the relationship of the C.C. to the probable error (F).

	II	III	IV	V	VI	VII	VIII	IX
I	+.572 10.56F	+.478 7.68F	+.224 2.93F	+.126 1.59F	+.037 .46F	+.030 .38F	+.343 4.82F	+.415 6.22F
II	—	+.176 2.25F	—.049 —.618F	+.101 .127F	+.128 1.62F	—.0427 —.530F	+.310 4.26F	+.403 5.98F
III	—	—	+.648 1.39F	+.116 1.45F	—.006 —.073F	—.038 —.473F	+.292 3.95F	+.286 3.86F
IV	—	—	—	+.048 .592F	+.003 .043F	—.098 —1.24F	+.165 2.1F	+.181 2.32F
V	—	—	—	—	+.512 8.56F	+.459 7.21F	+.486 7.89F	+.305 4.16F

VI	—	—	—	—	—	+.626 12.79F	+.460 7.23F	+.423 6.38F
VII	—	—	—	—	—	—	+.718 18.4F	+.217 2.83F
VIII	—	—	—	—	—	—	—	+.168 2.15F

It may be observed from Table II, that there exists high correlation between some regions and poor correlation between other regions. Thus, to illustrate positive and negative correlation coefficients, Region I is strongly correlated to Region II since the C.C. is +0.57; besides this positive C.C. it is also to be noted that the C.C. has a ratio as much as more than 10 times the probable error (F) viz., 10.56F. Region I again is well correlated with Region III, since the C.C. is +0.48 (approx.) while the ratio of the C.C. to the probable error is as much as nearly eight times, viz., 7.7 (approx.). This suggests therefore that the annual rainfall of Regions I, II and III are strongly correlated. It is then necessary to provide the physical explanation for such high positive correlations. The next step would be to prepare similar correlation coefficients between monthly rainfall, seasonal rainfall etc. of these same Regions. Once the physical causative factor or factors are established for the specific rainfall phases (annual, monthly or seasonal) it would be possible to compute correlation coefficients in respect of, for example, the Southwest monsoon rainfall of Region II and the pre-Southwest Monsoonal rainfall of Region I (since the latter is first exposed to the latter rainfall season because of its geographical 'aspect'). If the C.C. obtained in this connection is positively high and if the ratio of the C.C. to the probable error (F) is sufficiently high numerically, then it should be possible to 'forecast' the expected Southwest monsoonal rainfall (June to September) in Region II based on the known pre-Southwest monsoonal rainfall of Region I. The amount may even be numerically computed, assuming of course that the same physical factor is responsible for the pre-Southwest monsoonal rainfall and the Southwest monsoonal rainfall.

Likewise, it may be noted that Region VII has low correlation with Region I. Regions V, VI and VII are, however, strongly correlated for the C.C. has a high ratio in respect of the probable error. In respect of these regions in view of the positive C.C., further C.C. computation may be made in respect of other seasonal rainfalls, viz., between the pre-Northeast monsoonal rainfall and the Northeast rainfall.

POTENTIALITY OF CORRELATION COEFFICIENT FOR FURTHER CLIMATOLOGICAL RESEARCH IN CEYLON

The possibilities are therefore clear, that the use of a mathematical aid such as the correlation coefficient, would prove of real value in climatological investigations. In effect, the Indian Meteorological Department, even today uses C.C. values computed during the first decade of this century (Walker, 1906-1910). Walker attempted to correlate the Indian summer monsoon (Southwest monsoon) with world-wide factors, especially with the pressure-fluctuations in the southern hemisphere, designated the Southern Oscillation. The Indian Meteorological Department 'foreshadows' the Southwest Monsoonal rainfall on the

C.C. worked out, between the monsoonal rainfall and the winter seasonal rainfall of North-west India during the preceding year. The success has not been very encouraging, probably because it is now known that the physical causative factor is not sufficiently established for correlating these two phenomena.

A number of possible correlations may be established for Ceylon. Apart from the aforementioned references to the pre-Southwest monsoonal rainfall and the Southwest monsoonal rainfall and the pre-Northeast monsoonal rainfall and the Northeast monsoonal rainfall, C.Cs. may be computed between, for example, monthly or seasonal Dry Zone rainfall and the Southwest monsoonal rainfall of the Southwest Lowland or of the western flanks of the Central Highland. A graphically-expressed negative correlation seems to exist between the June—July rainfall of the Dry Zone and the May rainfall of the South-west Lowland, on the basis of a preliminary investigation by the author. This correlation is suggestive that when the May rainfall is positively anomalous for any year, the ensuing June rainfall of the Dry Zone shows proportionately negatively anomalous rainfall. Thus, in effect, an inverse relationship. Yet another preliminary graphical investigation using a scatter diagram with the drawing of regression lines, undertaken by the author, has revealed a strong negative correlation between the early August rainfall of the Central Highland stations and the late August rainfall of the stations within the Uva Basin. Here, it is obvious, that due to the greater orographic lifting of the monsoonal streamlines, the rainfall in the (over 5000-foot) Highland region is greater; due to the very same physical reason the consequent moisture-bereft monsoonal streamlines acquire greater adiabatic warming during the descent into the Uva Basin. Thus, any potentialities for convectional rainfall to occur is minimised.

In a different theme, the correlation coefficient method may be utilized. It is known that in the Tropics there is strong correlation between rainfall and sunspot activity; in some instances a positive relationship during sunspot maxima is to be observed and elsewhere a positive correlation during sunspot minima. If such relationships can be established between the rainfall of individual stations and supported by regional correlation, then it would be possible to 'forecast' with some degree of accuracy, on a long-term basis, rainfall incidence in Ceylon. Here again, this may be computed on a regional and a seasonal basis.

To an island like Ceylon, so strongly oriented agricultural-wise, it is imperative that techniques should be adopted to provide numerical forecasting of the vital rainfall incidence. It is no longer satisfactory to rely on mean values computed from highly variable data-series. To adopt such values without any reserve, in the planning and guiding of agricultural programmes in Ceylon, would be extremely fool-hardy. Already past experience itself should have demonstrated, that too much reliance on the 'arrival dates' of the monsoonal rainfall, has been responsible for ruination of crops and ensuing acute economic hardship. It is necessary that a re-orientation of outlook must guide the agriculturalists of Ceylon and to this end agro-climatological investigations must be promoted. Mathematically-trained personnel should also constitute part of the Organizations involved in agro-climatological research.

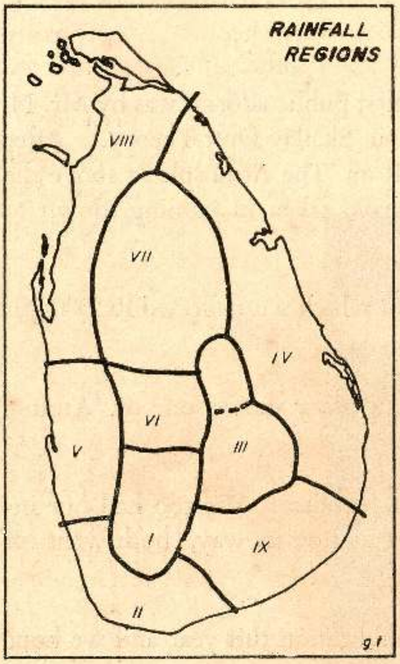


Figure 1. Rainfall Regions of Ceylon, used for the computation of Correlation Coefficients indicated in Table II.

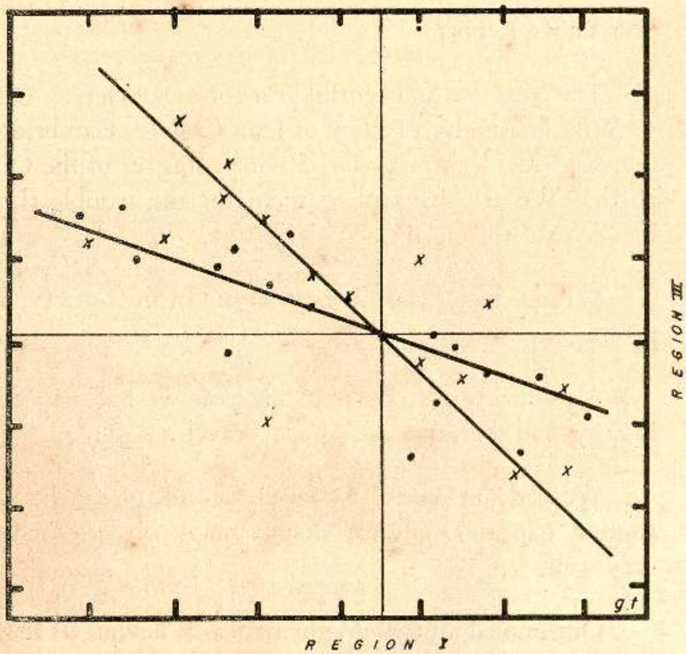


Figure 2. Scatter diagram showing the construction of regression lines to determine graphically the existense of any possible correlation between the annual rainfall of Regions I and III (Figure I). The narrow angle formed by the intersection of the regression lines justified the computation of the Correlation Coefficients (Table II).

REFERENCES CITED

BROOKS, C. E. P. AND CARRUTHERS, N. 1953 : *Handbook of Statistical Methods in Meteorology*, (London : H. M. Stationery Office).

CONRAD, V. AND POLLACK, L. W. 1950 : *Methods in Climatology*, (Harvard University Press).

CROWE, P. R. 1933 : The Analysis of Rainfall Probability., *Scottish Geographical Magazine*, vol. XLIX.

LANDSBERG, H. 1943 : *Recent Climatic Fluctuations*, (Hobenhavn).

Meteorologial Glossary,1939 : (London : H. M. Stationery Office).

THAMBYAHPILLAY, G. 1958a : *Climatic Fluctuations in Ceylon*, (Ph.D. Thesis : University of Cambridge). Vols. I, II and III.

1958b : The Investigation of Climatic Fluctuation, *The Ceylon Geographer*, vol. 12, (Nos. 1 & 2).

1959 : Rainfall Fluctuations in Ceylon, *The Ceylon Geographer*, vol. 12 (Nos. 3 & 4).

1960a : Sunspot Cycles and the Climate of Colombo., *University of Ceylon Review*, vol. XVIII (Nos. 1 and 2).

1960b : Agro-Climatological Significance of Rainfall Variability in Ceylon., *Agriculture*, vol. 3.

WALKER, G. G. 1906—1910 : Correlations in Seasonal Variation of Climate, *Indian Meteorological Memoirs*, vol. XX (Part VI).

Secretary's Report.

This year was an eventful year for our society. Our first public address was by Mr. N. C. Wikramasingha a Fellow of Jesus College, Cambridge on 'Skallav Dust Theory.' After that we had a lecture by Dr. S. Gnanalingam of the CISIR on 'The Atmosphere above the Earth. We are thankful to them for the trouble they have taken in coming down to Peradeniya wasting their valuable time.

We also had a benefit show in aid of the Society, from which we collected Rs. 300/- as profit.

Also during the course of the year we had two documentary shows, one on 'Atomic Energy' and the other on 'Space Travel'.

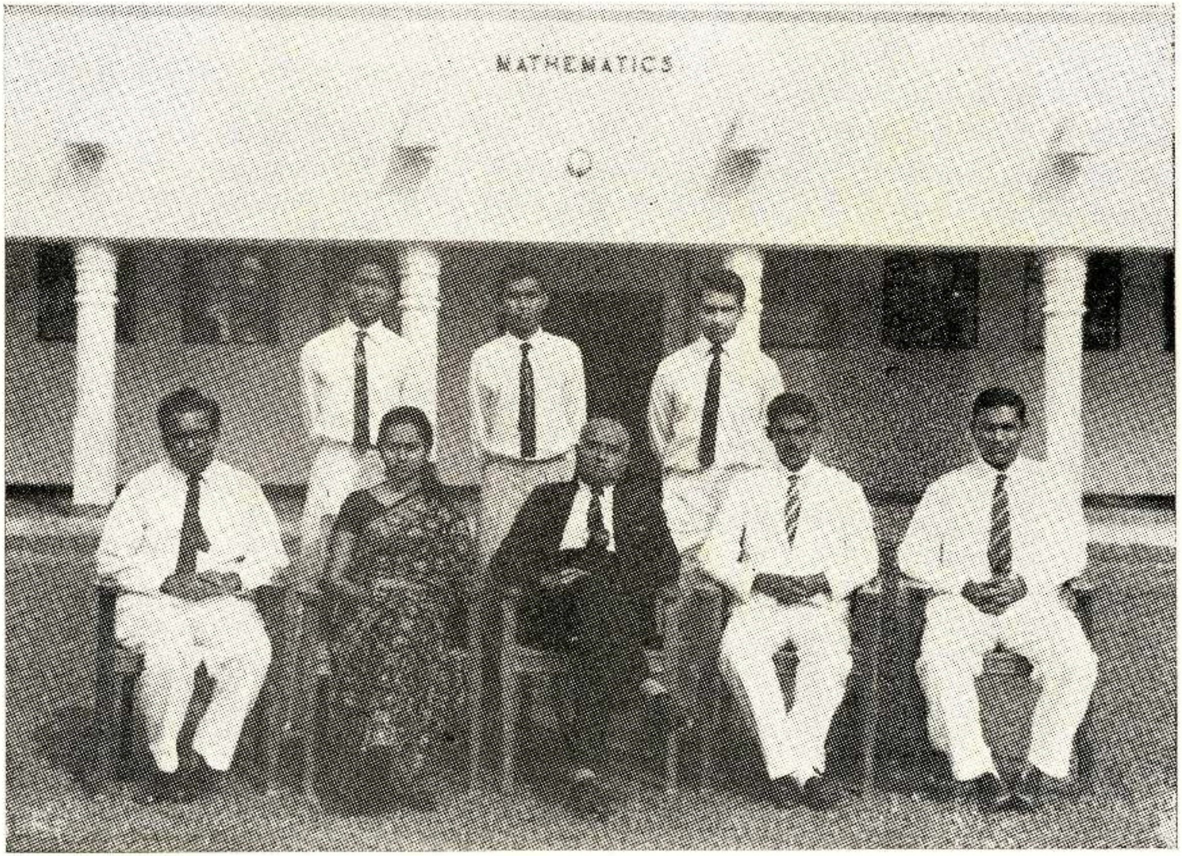
We had our annual Social at the end of the 1st term in office. We too had our inaugural trip to Dunhinda despite many obstacles which came on its way, both went off very well.

Our annual Journal 'Mathematica' is having its first publication this year and we hope that this would be continued every year.

At end of last year we had to say good bye to one of our young lecturers Dr. Wilson who left this University Staff to join a foreign University. In September 63, Dr. P. Kanagasabapathy our Patron left the island on a holiday cum Study tour to U.K.

Finally I wish to thank Mr. P. Kanagasabapathy and Dr. C. R. Kulatillaka and other members of the Staff for their valuable assistance rendered to the Mathematical Society.

Sunil Ajantha,
Secretary.



Seated : Mr. C. R. Kulatillake, Miss Brenda Gunawardena, The Vice-Chancellor (Patron), Mr. Solomon Pakiam, Mr. M. Maheswaran (Senior Treasurer).

Standing : Mr. Sarath Weeraman, Mr. Sunil Ajantha, Mr. Dudley Jayatillake.

IMPACT OF SPACE EXPLORATION ON SCIENCE

T. Anver Dole
First Year-Science

Man, the restless being that he is, is always striving to conquer new fields. Space exploration is his latest interest. It is a field in which knowledge and data obtainable are limitless. Indeed, the impact of space exploration on Science has been so tremendous, that space exploration has become a firmly established activity of the human race. The discovery of the Great Radiation Belts about the earth, announced by James Van Allen of the State University of Iowa, four years ago, is an outstanding example of a significant advance in space Science. These Van Allen Radiation Belts have been found to be composed of streams of charged particles trapped in the Earth's magnetic field. When these particles impinge on the spacecraft and its contents, radiation is produced.

Manned exploration of space has resulted in tremendous technological growth. As a result major advances are being made in energy—conversion devices, computers, data collection and handling, electronics, new materials and communications. Protective equipment for man in hostile environments is being improved upon and increased knowledge is being obtained on the behaviour of the human body under stress.

The space age has introduced the concept of systems analysis and optimization of designs involving many branches of Science and technology. It has resulted in the perfection of computers handling complex data, ablating materials for heat protection, high-temperature ceramics, light-weight tanks which have been pressure stabilized and a series of other developments which are finding more and more applications in modern industry.

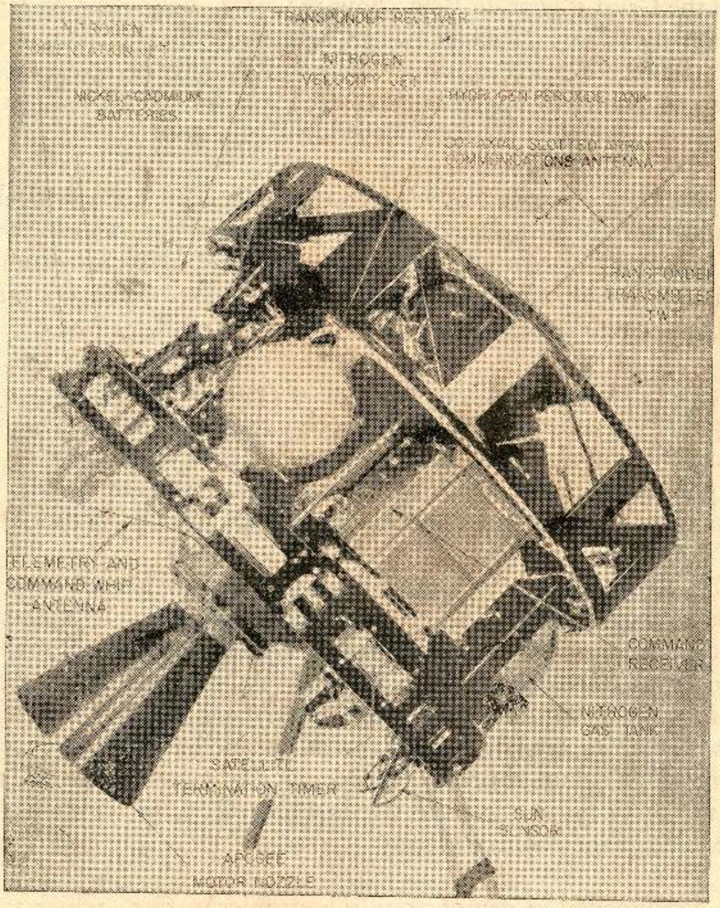
On July 10th, 1962, history was enacted when America launched the first communications satellite in space. TELSTAR, it was called, weighed one hundred and seventy pounds (76.5 kilo-grams) and was hurled into space by a ninety foot (27 meter) Thor Delta rocket, launched from Cape Canaveral in Florida. As intended it traversed an elliptical trajectory reaching out 3,503 miles (5,605 kilometers) and dipping at its closest point to within 593 miles (949 kilometers) of earth. Telstar was inclined 44.8 degrees to the Equator and took 157.8 mts. for a complete orbit. This meant that several orbits had to elapse before the rotation of the earth underneath the satellite brought it to within range of tracking stations on either side of the Atlantic Ocean.

Telstar was instrumental in demonstrating how microwaves—which travel in straight lines and do not follow the earth's curvature—can be transmitted over extensive limits by a relay tower suspended in the sky.

Microwave is a broad-band radio system. It had hitherto been used only in overland communications. Its high reliability and quality render it ideal for all types of telecommunications and messages. Employing a satellite aa a microwave bridge across the ocean was undoubtedly a significant achievement.

Within the next decade communications satellites will greatly expand facilities for telephone, telegraph and television. It will prove to be a serious threat to submarine telephone cables.

Presently, two types of communications satellites have been tested. They are of the "passive" type and the "active repeater" type to which Telstar belongs. The "passive" type reflects radio waves between two points on earth. The latter type acts as a miniature radio station, receiving signals beamed from one ground station and relaying it to another.



If a network of communications satellites is to be a success, then it must be practical from an economic standpoint, in addition to being infallible in construction. The innumerable components in the satellite must be capable of sustenance over a protracted period of time. Its delicate electronic instruments must be shielded from deadly radiation. The vital solar cells of the satellites must resist the shower of meteoroids likely to impinge on it. These solar cells are important because sunlight striking these flocks of solar cells is converted into energy which is stored in nickel cadmium batteries for operating the instruments.

Now, unlike a submarine cable which can be payed out from one end of a ship and laid on the ocean floor, a satellite is always on the move and is never static. Thus, if the satellite is to be electronically visible to the ground tracking stations using it, then it must be at a conveniently high altitude. The optimum height at which such a network of satellites must operate has to be determined if the venture is to be a success.

Some scientists make bold to predict that one day powerful satellites will trasmit telecasts to home receivers in the distant reaches of the globe, thus eliminating coaxial cables and other encumbrous ground relay equipment.

Technical data could be exchanged between continents, via microwave, by computers storing vast amounts of vital information indispensable for industry and research purposes.

Facsimile, a radio system capable of transmitting graphic material such as charts and pictures could become firmly established and the transmission of telegrams and photographs could be greatly speeded.

Recently launched satellites have also made other gains in space knowledge. For example, it has been discovered that at altitudes of 600 and 1,500 miles there exists a layer of helium which surrounds the earth. In addition, it is now known that the magnetic fields in interplanetary space are at times much more intense than had been previously conceived.

By solving the equations of motion mathematically it has been determined that closed or repeating orbits are elliptical in shape. The shape of the orbit depended upon the fact that the force of gravity varies inversely as the square of the distance. If, by chance, gravity varied as some other power of the distance—say the cube or the fourth power—the orbit traversed by an object may have been some other mathematical curve.

The shape of a satellite's orbit is dependent upon the speed. By experimentation it has been found that at a speed below 5 miles per sec. the satellite falls back to earth. At 5 miles per sec. the object descends to Earth at exactly the same rate that the Earth curves away from it and the resulting orbit is circular and it is a special case of an ellipse, in which both foci coincide with the centre of the orbit.

Between 5 and 7 miles per sec. the orbit is elliptical. As the speed of launching is increased to 7 miles per sec., the orbit is rendered increasingly eccentric and the satellite swings further out from Earth. When this speed reaches 7 miles per sec. we have a parabola. If the launching speed is further increased to greater than seven miles per sec., it goes forth on an hyperbolic orbit, at this speed the satellite has a sufficient store of energy to "just not return" to Earth.

Those who are mathematically inclined will appreciate the following famous formula of celestial mechanics.

The formula is:

$$V = \sqrt{GM\left(\frac{2}{r} - \frac{1}{a}\right)}.$$

V is the speed of one object with respect to the other, '*r*' the instantaneous position of the object in its orbit and '*a*' the semi-major axis of the orbit (one-half the long axis). *G* and M are constants, representing the gravitational force and the sum of the masses of the two bodies, respectively.

The above formula holds only when one object is in orbit around another and is undisturbed by the presence of other bodies.

If for example the speed of Venus around the Sun is required at any moment, then by simply substituting its distance '*r*' from the Sun at that moment and its average distance '*a*' from the Sun, in the formula, its speed *V* is easily obtained by solving.

The variations in this formula are of great interest. In a circular orbit, *r* equals '*a*' and the formula reduces to:

$$V_{circ} = \sqrt{\frac{GM}{r}}.$$

when the orbit is parabolic, '*a*' is infinitely large and consequently $1/a$ tends to zero. The formula then becomes:

$$V_{par} = \sqrt{\frac{2\,GM}{r}}.$$

Therefore the relation between the two expressions is,

$$V_{par} = \sqrt{2} \times V_{circ}.$$

It is thus seen that if the circular velocity of a satellite near the Earth is 5 miles per sec., an object must be launched at a speed of $\sqrt{2} \times 5$, or approximately 7 miles per sec., in order never to return back to Earth.

Another fascinating law of celestial mechanics facilitates the determination of the ratios of the planetary distances. This law states that the periods of the planets (a period being the time taken to make one circuit around the Sun), are exactly related to their distances from the Sun in the following manner:

$$\frac{P_1^2}{P_2^2} \times \left(\frac{m_1 + S}{m_2 + S}\right) = \frac{D_1^3}{D_2^3}, \text{ where}$$

P = period, m_1 and m_2 the masses of the respective planets, S the mass of the Sun and D_1, D_2 the distances from the Sun of the respective planets.

Since the masses of the planets are virtually negligible in comparison to the mass of the Sun, the formula simplifies to:

$$\frac{P_1^2}{P_2^2} = \frac{D_1^3}{D_2^3}.$$

i.e. the square of the period of a planet is directly proportional to the cube of its distance from the Sun.

Now, the period of the Earth is 1 (one year) and the distance of the Earth from the Sun is 1 astronomical unit (by definition), consequently our formula becomes,

$$\frac{E_1^2}{1} = \frac{D_1^3}{1}\text{, i.e. } E_1^2 = D_1^3.$$

In this form it is identified as Kepler's Harmonic Law.

Therefore by observing how long it takes a planet to revolve round the Sun, the exact distance of the planet from the Sun (taking Earth as standard) may be determined without much difficulty.

The tabulation given below of the period, and the distance from the Sun of the different planets, may be verified by the application of Kepler's Harmonic Law. $(P_3^2 = D^3)$.

Planet	*Period* (years)	*D* (*A.U.*)
Mercury	0.241	0.387
Venus	0.615	0.723
Earth	1.0	1.0
Mars	1.8808	1.523688
Jupiter	11.86	5.20
Saturn	29.46	9.54
Uranus	84.01	19.18
Neptune	164.79	30.06
Pluto	248.43	39.52

On squaring the period the value obtained will tally with the distance cubed. For Mars, $P^2 = 3.573$, $D^3 = 3.573$ and for Uranus $P^2 = 7060.0$ and $D^3 = 7060.0$.

Hundreds of aircraft crowd the skies over a greater portion of the world and it is estimated that there are twenty thousand surface craft at all times on the Atlantic ocean alone. These numbers will increase by leaps and bounds as time marches on, and accordingly information as to his exact location has become a vital necessity to the navigator of every sea or aircraft. It is in this context that navigational satellites assume their importance.

The "steady state theory," which was one version of a major theory of the origin of the universe was recently discredited as a direct result of space exploration. This theory maintains that matter and antimatter are being continuously created in space at a slow rate, thus creating in time new stars and galaxies in the voids between those existing, which appear to be rushing apart at enormous velocities. According to this version of the theory, the appearance of new stars and galaxies would maintain a steady state of star and galaxy distribution in any given region of the universe.

But, the physicist steadfastly maintains that if matter were being continuously created in this way, there would have to be steady production of gamma rays in space. Since the atmosphere would absorb these gamma rays they could not be detected from the Earth's surface and hence a satellite orbiting above the earth had to be employed.

With this aim in view, on the 21st of April, 1961, the NASA of America launched a satellite Explorer XI, laden with instruments to detect gamma radiation. An analysis of the reports telemetered from Explorer XI to the Earth resulted in the discovery of the fact that the radiation detected was a thousand times less intense than would have to be the case if matter and antimatter were being created at equal rates. Thus the Explorer XI experiment has discredited this version of the theory.

Exploration of the moon's surface will dispel many doubts and misconceptions about the origin of the solar system. A study of the lunar surface as well as the internal structure of the moon may provide a clue to the early history of the solar system and the birth of ten planets.

Improved rocket power will facilitate launching of multipurpose satellites, which will carry a large numbers of experiments designed to make coordinated observations. With this objective the Orbiting Solar Observatory(OSO) was launched on March 7th, by America, with thirteen experiments aboard. One of the main instruments was an X-ray spectrometer covering the range 100 to 400 angstroms, a region of the spectrum which is absorbed by the Earth's atmosphere. Sporadic explosive outbursts of X-rays are synchronized with solar flares. Late this year or early 1964 it plans to put into space the Orbiting Astronomical Observatory, which will carry a 36-inch reflecting telescope and other intricate equipment to make an exhaustive study of phenomena in the distant reaches of the Universe.

Biologists have formulated extensive programmes for extra-terrestrial life, and the study of the effects of unaccustomed environments on living organisms. Certain animate organisms are suspected to exist on the moon and the planets. For example, eighteen microbial candidates that could possibly exist on Mars, has been listed, and a host of ingenious devices have been developed which if landed on Mars could report back evidence of life similar to those suspected by the designers of the devices.

One of the significant benefits that have accrued from space exploration is weather observation and prediction. The sun's reflections on clouds and the earth's surface are recorded and tabulated by complex devices such as Vanguard II, which has ushered a new era in meteorology. In one day it is able to report over 25 per cent of the Earth's sunlit surface, in a series of 300 mile-wide pictures. Clearly, an improved form of this device will be a godsend to weather sensitive industries such as shipping, airlines, agriculture and construction.

Satellites equipped with infra-red sensors, cameras and television are making possible observations over areas not previously covered. It will be possible to give warnings of blizzards, hurricanes, tornadoes, floods and other catastrophic weather, enabling people to strengthen levees and take adequate precautions. Soon, the possibility of modifying the world's weather to better suit man generally, in addition to ensuring crops in areas hitherto unproductive, will be a reality.

Space exploration has undoubtedly revolutionized science. There is indeed no end to man's capacity for growth and adaptation, and it would therefore be furtile to predict the ultimate destiny of man. Space exploration has opened new and exciting vistas for science. But one point must be stressed. It is earnestly hoped, that the potential benefits to be gained from aeronautical and space activities, will be utilized strictly for peaceful and scientific pursuits, and not for destructive purposes which all mankind fervently dreads.

For Cheaper Prices
and Better Service

Always Visit

Kandy Tea Stores

Stockists of :

SHIRTS OF ALL VARIETIES, SLACKS, SHORTS, BRIDAL OUTFITS, SAREES, TWEEDS, HIGH GROWN TEA, FANCY GOODS, COSTUME JEWELLERY ETC.

Kandy Tea Stores

2 & 11, Yatinuwara Vidiya,
KANDY.

Phone : **7193.**

SILVERDALE

FOR

That Special Occasion of Yours

WEDDINGS
FAREWELL
FUNCTIONS
&
FOOD PARCELS

Caterers, Bakers and
Ice Cream Makers.

KANDY.

Phone: **298.** Grams: **"CITYDALE".**

Visit

CITY PHARMACY

50, TRINCOMALEE STREET,
KANDY.

For

ALL YOUR MEDICAL REQUIREMENTS

DISPENSING SERVICE

DAY AND NIGHT

TELEPHONE 630

SILVER EXIDE BATTERIES

Sales & Service

K. H. M. FERNANDO & CO.,
KANDY.

Phone: **275.**

Printed at the Ceylon University Press, Colombo 3, by R. L. de Alwis, Printer to the University of Ceylon, and published by the Editor, Mathematical Society, University of Ceylon, Peradeniya.