UNIVERSITY OF ILORIN

THE 7TH INAUGURAL LECTURE

THE ATMOSPHERE OF PHYSICS AND PHYSICS OF THE ATMOSPHERE

By:

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THE ATMOSPHERE OF PHYSICS AND PHYSICS OF THE ATMOSPHERE

THE VICE-CHANCELLOR, REGISTRAR, DEANS OF FACULTIES, LADIES AND GENTLEMEN.

1. INTRODUCTION

The topic "The atmosphere of physics and physics of the atmosphere" has been chosen in order to enable me present a brief review of the general developments of both the main ideas of the subject, physics, and the study of the physical properties and characteristics of the atmosphere of our planet, earth. I wish first of all to relate the story of my earliest personal meditation and expressed interest that I can clearly remember and that relates directly to both the subject, physics, and an atmospheric phenomenon.

As a Form IV school boy in December 1953, I was proceeding on Christmas vacation with other schoolmates from Government College, Keffi, then located temporarily in Kaduna. The train bringing us from Kaduna had arrived at Ilorin railway station punctually at about 4.00 p.m., (trains were fairly punctual in those days). By a previous joint arrangement between the college and our native authority ("N.A") office, an open lorry was already waiting for us outside the station. Soon after, we were happily seated facing backwards on the lorry which then headed due east on the Ilorin – Lokoja road, which was then a laterite covered road. Shortly afterwards, and looking through the trailing dust raised by the lorry, I and the other happy passengers were face to face with the brilliant orange ball of the setting sun. I then turned to an older hitch-hiking passenger who was a student of a college then called the Nigerian College of Arts, Science and Technology, Zaria, and I asked him why the sun's colour changed progressively from dazzling white around mid-day to yellow, orange and red at sun-set. He replied gently that he did not know and promptly reminded me that he was an “arts student”. The answer was finally to come my way several years later when I participated as a physics undergraduate in the demonstration experiment on the “sun-set effect” during the Open Day activities of the Department of Physics of the University College, Ibadan, in 1960.

During the demonstrations, I learnt with great joy and satisfaction a few simple facts about the colours of the sun and the sky as seen from the earth’s surface. Firstly, that the blue colour of the clean and cloudless sky is due to the preferential scattering of the various colour-components of sunlight by the molecules of the gases constituting air. This scattering, which is known as “Rayleigh scattering”, is such that the intensity of the scattered light is inversely proportional to the fourth power of the wavelength. The shorter the wavelength of the light the greater the scattering. This implies that violet and blue components of sunlight, which have the shortest wavelengths, get scattered out of the direct path more easily than yellow, orange and red which have longer wavelengths. During sunset, the direct rays from the sun reaching the observer’s eye traverse a longer oblique path through the atmosphere, than at other times of the day, and so giving the right situation for nearly all the blue component to be scattered out, leaving the other components, green, yellow, orange and red which together make the sun initially appear yellowish. With further descent of the sun, these colours also suffer significant scattering in that order, until finally the setting sun appears deep red.

The second simple fact which I learnt was that sky light is partially polarized. The demonstration teaches many other important physical principles, but to which no more time needs be devoted in this lecture. However, an account of the experiment may be found in Jenkins and White's text entitled "Fundamentals of Optics". [1]

As the occasion of sitting in an open lorry 29 years ago provided me with the opportunity of watching and reflecting on the beauty of the western sky, so has the occasion of this lecture provided me with the opportunity of reflecting or trying to reflect as much as possible on the whole field, as it were the whole atmosphere, of the fascinating subject which I profess. Unfortunately, I must at the same time confess that I neither have the capability to comprehend nor the time now to relate all the detailed features of the field. However, for the purposes of this lecture, I believe it would suffice to:

- firstly look briefly at the 'dusking' western horizon to see the past development of the ideas of physics;
- secondly look around to see some of the major current or gross features of ideas;
- thirdly look eastwards to see the 'dawning' horizon of the subject's frontiers of ideas;
- fourthly look at the local and immediate environment of physics in Nigeria and at Ilorin and
- finally discuss briefly a few applications of the ideas and methods of physics to the study of our atmosphere.

2. THE ATMOSPHERE OF PHYSICS

2.1 Scope and Aims of Natural Philosophy – Physics

The Mitchell Beazley Joy of Knowledge Encyclopedia [2], 1978 defines physics as follows, "physics is the study of matter and energy. Both matter and energy appear in many forms and physics seeks to see beyond these forms and to connect them in their manifestations". Modern physics recognizes four basic forces in nature and these are categorized according to the interactions they induce.

The first of these is **GRAVITATIONAL** force, which was first adequately described by Isaac Newton (1642 – 1727).

The second is the **WEAK** force, which is responsible for the decay of some sub-atomic particles.

The third is the **ELECTROMAGNETIC** force, which was codified in Maxwell's Equation in the 19th century.

The fourth is the **STRONG** force which binds together atomic nuclei. This strong force is some 10^{12} (one million million) times stronger than the weak force and, as will be shown later, is the least well understood in physics.

Physics may be divided into six fundamental theories. Newtonian or Classical Mechanics, Thermodynamics, Electromagnetism, Statistical Mechanics, Quantum Mechanics and Relativity.

In order to comprehend easily the whole view of the subject, attention will shortly be focused on each of these six disciplines one at a time. However, before doing so, the aim of physics, and indeed that of natural science, must be clearly borne in mind. Albert Einstein [3] and Leopold Infield in their book entitled "The evolution of physics", described the first philosophical ideas on the aim of science, as follows,

> *In the whole history of science from Greek Philosophy to modern physics there have been constant attempts to reduce the apparent complexity of natural phenomena to some simple fundamental ideas and relations. This is the underlying principle of all natural philosophy.*

This aim re-echoes in the words of Dr. Tsung Dae Lee who shared the 1957 Nobel Prize for physics with Dr. Chen Ning Yang for their discovery of non-conservation of parity and work in elementary particle theory, [4] *The purpose of science is to seek for that simple set of fundamental principles through which all known facts are understood and new results predicted.*

2.2 The Ancient Western Horizon

That underlying principle was implied even in the works of the Atomists, the first one of whom was the Greek philosopher Democritus of Adhera [3] (460 - 370 B.C.) who wrote:

> *By convention sweet is sweet, by convention bitter is bitter, by convention hot is hot, by convention cold is cold by convention colour is colour. But in reality there are atoms and the void. That is, the objects of sense are supposed to be real and it is customary to regard them as such, but in truth they are not. Only the atoms and the void are real.*

Unfortunately, this kind of principle pronounced by Democritus remained in ancient philosophy merely as an ingenious figment of imagination and was not developed, not even by Artistotle (384 – 322 B.C.) who lived only a generation later. The idea was not developed because scientific reasoning was unknown to the other Greek philosophers who rather employed the method of reasoning dictated by intuition.

2.3 **Newtonian Mechanics** (or Classical Mechanics).

Mechanics is a branch of physics concerned with the behaviour of matter under the influence of force. Newtonian or classical mechanics was the first form of mechanics to be developed, even though its development was much delayed. The delay was due to the method of reasoning dictated by intuition as mentioned above – a method which was wrong and led to false ideas of motion which were held for centuries. Aristotle's great authority throughout Europe was said to be probably the chief reason for the long belief in this intuitive idea. For example, in the book "Mechanics" attributed to Aristotle, people read for two thousand years the following:

> *The moving body comes to a standstill when the force which pushes it along can no longer so act as to push it.*

It is obvious that this statement gave a wrong idea on motion, because we do know that a moving body may continue to move when the applied force is removed. None-the-less, Aristotle's wrong idea on motion was held for about two thousand years!

The science connecting theory and experiment really began with the work of Galileo (1564 – 1642), who used actual experiments to prove his theories. On the impact of Galileo's work on science, Einstein and Infeld [5] had this to say:

> *The discovery and use of scientific reasoning by Galileo was one of the most important achievements in the history of human thought, and marks the real beginning of physics. This discovery taught us that intuitive conclusions based on immediate observation are not always to be trusted, for they sometimes lead to the wrong clews.*

Galileo first correctly connected force and motion of matter, and used experiments on the timing of falling bodies and the pendulum to prove the connections.

A generation later the ideas on motion were formulated by Sir Isaac Newton (1642 – 1727). In his publication: Philosophies Naturalis Principia Mathematical (1687), he outlined among other things the laws of motion and proposed the principle of universal gravitation. Every school boy knows the three Newton's laws of motion:

The first law says, quoting from a school text [6],

> *Every body continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed on it.*

The wordings of the second and third laws of motion and the law of universal gravitation may be found in any physics school text. The first law has been quoted here in order to illustrate the complete departure from Aristotle's wrong idea of force and motion. Newton's discoveries in mechanics and other fields have guided the thinking of physicists ever since. His mechanics' striking achievements in the development of astronomy, machines, technology and even the kinetic theory of gases, led scientists to believe that all natural phenomena could be described in terms of simple forces between unalterable objects, with the forces acting along the lines joining the objects. This view was held for nearly two hundred years until the discovery of the field theory, as will be seen later.

2.4 Thermodynamics

Thermodynamics remains a valid principle having important and wide applications in chemistry and engineering generally, but its laws on 'entropy' and conservation of energy, can now be derived from statistical and quantum principles. Thus the historical discipline of thermodynamics is now subsumed in the discipline of statistical mechanics or quantum mechanics, as will be shown later.

2.5 Electromagnetism

It is believed that the magnet was known to the ancient Greeks and Chinese, and that the first name given to magnetic objects was "lodestone". The electric charge, also known and called the "electron" by the ancient Greek, was found by Charles Coulomb (1736 – 1806) to exert on other charges forces of attraction or repulsion which obeyed the inverse square law. This discovery fitted easily into the prevailing Newtonian mechanical concept of simple forces between objects mentioned before, because the forces due to the charges did act along the lines joining the charges. However, the discoveries of Oersted (1777 – 1851) and Faraday (1791 – 1867) revealed a new aspect of the atmosphere of science. They showed that magnets and current-carrying wires mutually produced forces which acted, not along, but at right-angles to the lines joining them. This led to the discovery of the field theory. The two pillars of support of the field theory are:

(i) A changing magnetic field is accompanied by an electric field.

(ii) A changing electric field is accompanied by a magnetic field.

(One statement can be obtained from the other by simply interchanging the words "electric" and "magnetic".) The first "pillar", connecting the changing magnetic field with the induced current, arose from Faraday's experiment; while the second "pillar" rose from Oersted's experiment on the deflection of a magnetic needle by a current-carrying wire. These concepts were contained in the new theory formulated in 1873 by Clerk Maxwell (1831 – 1879) as Maxwell's equations of electromagnetism. The characteristic features of Maxwell's equations also have since appeared in all other equations in modern physics. These characteristics have been summarized by Einsten[5] and Infeld in one sentence:

> *Maxwell's equations are laws representing the structure of the field; they enable us to follow the history of the field, just as the mechanical equations enabled us to follow the history of material particles.*

Following Maxwell's predictions, Heinrick Rudolf Hertz (1857 –1894) proved, for the first time, the existence of electromagnetic wave (or radio waves) and confirmed experimentally that their velocity is equal to that of light. Thus electromagnetic theory revealed a new and bright area of the atmosphere of physics.

2.6 The Dawning Eastern Horizon – Statistical and Quantum Mechanics

At the turn of the century, experimental observations revealed a great deal of new phenomena, among which were the spectrum of black-body radiation, spectral lines of radiation from gas discharges, the discovery of the electron by J.J. Thomson (1856 – 1940), radioactivity, photoelectric effect and diffraction of electron waves. These effects could not be described solely in terms of the forces and fields known at the time. However, the lead in explaining them was made by Max Planck (1858 – 1947) when in 1900 he proposed that radiation was emitted in separate packets called "quanta". The energy of the quantum of radiation, which is called photon, depends entirely on and varies directly as the frequency of the radiation. In the new picture, light is a shower of photons. In my opening story on red and blue colours of sunlight, I said that the wavelength of red light was longer than that of blue light. There, I was using the terminology of the wave theory, where one could say that homogeneous light had a definite wavelength. Translated into the terminology of the quantum theory the statements above would now read: homogeneous light contains photons of a definite energy, and the energy of the photons of red light is less than that of blue light.

That radiation was quantized was re-inforced by the work of Albert Einstein (1879 – 1955) on photo-electricity. A beam of electrons, which were ordinarily regarded as particles, revealed wave-like character through the diffraction effect that the beam produced. This effect is the "particle – wave duality" – a new principle in physics. The emissions resulting from radio-active decay and the electron diffraction effect were clearly statistical in nature. Hence, these phenomena revealing the particle and wave nature of matter and radiation, and the apparently statistical character of the elementary events mentioned above, forced physicists to develop the new approach of quantum physics.

Quantum physics comprises equations of probability waves, suitable for describing the dual particle-wave and statistical phenomena. Classical and quantum physics differ radically. Classical physics aims at a description of objects existing in space and the formulation of laws governing their changes in time. But quantum physics comprises laws governing the changes in time of probability. For instance, quantum physics does not tell us the position and velocity of an electron (or any other nuclear particle) at any moment, because such a question has no sense in quantum physics. But it will tell us the probability of finding an electron on a particular spot, or where we have the greatest chance of finding an electron.

The works of the following winners of Nobel Prizes, Albert Einstein, Niel Bohr, Louis de Broglie, Karl Heissenburg, Enrico Fermi, Erwin Schrodinger, Paul Dirac, Max Born and many twentieth centry and contemporary physicists, have now firmly established the laws of quantum mechanics; which are so embracing and general that classical mechanics can be shown to be special cases approximating to the general laws.

2.7 Relativity

The theory of relativity proposed by Albert Einstein, links the concepts of space and time. It replaces the concept of three-dimensional space and the independent unidimensional time with the concept of four – dimensional space – time. The theory was proposed in two steps: the special theory of relativity and the general theory of relativity.

The special theory shows that the old laws of mechanics are invalid if the velocity of the moving particles approaches that of light. It further shows the connection between mass and energy. It can be said correctly now that mass is energy and energy is mass.

The general theory attacks the problem of gravitation and formulates new structure laws for the gravitation field. The predictions of the General Theory has been verified by the observed rotation of the elliptical orbit of the planet mercury round the sun. The gravitational field of the sun is so very strong at the position of mercury's orbit that the motion of the planet deviates from the Newtonian law.

Vice-Chancellor, Sir, this review firstly of classical physics (comprising Newtonian forces and Maxwellian fields) and then quantum mechanics and relativity has brought us, as it were, from the ancient western horizon through the zenith to the "dawning" eastern horizon of the atmosphere of physics. This "dawning" eastern horizon adjourns the very frontiers of physics.

2.8 Frontiers of Physics

High energy physics, which is also referred to as particle physics is generally considered to occupy a position on the frontiers of ideas in physics, and indeed of the whole of natural science. There are at least two stretches to these frontiers. Firstly, there are still fundamental questions in the domain of heavy particles constituting the nuclei. High energy collisions between particles in accelerators have produced new particles. There are over 200 nuclei particles now known, most of them very stable. They are classified broadly into two groups, called hardrons and leptons. The hardrons are the particles that partake in strong interactions – including nucleon, hyperons and mesons; while the leptons are particles that do not take part in strong interactions, including electrons and neutrinos. The problem of high-energy physics is to produce a single theory explaining the existence and behaviour of this multitude of particles.

The other stretch of the frontiers to be mentioned here is the creation of a single theory to account for all the types of interactions or forces. I mentioned earlier that there were four basic forces which were yet to be unified. However, these four forces have recently been reduced to three by professor Abdus Salam in unifying the electromagnetic and weak forces into one force now known as the “electro-weak” force. For this achievement, Professor Abdus Salam, a Pakistani, was awarded the Nobel Prize in Physics in 1970.

2.9 Our Local Atmosphere

Having considered the global atmosphere of physics, attention should now be drawn to our local atmosphere in Nigeria and Ilorin. It is right for me to do this especially because I have been given the privilege of being the first and only Head of the Department of Physics at this University from September 1977 to date.

The Department experiences the world-wide difficulty in recruiting, in sufficient numbers, qualified staff and students. However, it has been able to plan and teach, with every determination, all the basic disciplines of physics which are the ideas already mentioned above, as well as the appropriate experimental techniques of measurements.

Practical work is strongly emphasized at all levels, so that students may achieve clear understanding of the principles of physics and become equipped for future work in education, industry or research. The Department also emphasizes the use of carefully selected demonstration experiments to augment the routine laboratory ones. Some additional courses in the areas of applied physics such as electronics and geophysics, are also given to students "majoring" in physics. Such students also take a substantial number of carefully selected mathematical courses in the Department of Mathematics to enable them gain fluency in that important "language" of physics.

Due attention is also paid to the "service" component of our teaching of other students taking some courses in physics as their minor subject. For instance, in response to an expressed need of the Faculty of Health Sciences, we expanded slightly the treatment of viscous flow through tubes at 100 level, simulating roughly the flow through blood vessels. We will remain responsive to such special needs of users of physics courses.

Our first product of the Department graduated in June 1980, and the next crop comprised eight students who graduated with B.Sc. Honours in Physics in June 1981, with one of them achieving a First Class Honours degree. We are delighted that some of them are seriously planning to embark upon postgraduate studies. We have high hopes that they will perform well in the graduate schools of other Universities in Nigeria and abroad, as this could be a sure measure of the standard of our teaching.

Postgraduate and Research Programmes

The Department has embarked upon a Masters programme and admitted its first student in this session, while provisions are now being made for a logical expansion of the programme for Ph.D. work next session.

The Department upholds the idea that no progressive and creditable university teaching can be sustained by the staff without such staff engaging in some serious research work. The research interests of the staff are in the following broad fields: plasma physics, solid state and materials physics, solar energy development and atmospheric physics. More details on atmospheric physics will be given in section 3 below, while brief mention will now be made of the other research fields.

Thin Film Resistors

In the field of materials science, there is a project to investigate the electrical and thermal properties of two types of thin film resistors, namely (i) carbon black/clay mixtures and (ii) carbon black/polyvinyl acetate mixture. A knowledge of these properties may lead to the local production of reliable thin film resistors from locally available materials.

Solar Energy Development

There have been growing drives, nationally and internationally for the development of solar energy. At the United Nations Conference on New and Renewable Sources of Energy held in Nairobi, in August 1981, resolutions were passed on the development of new and renewable sources of energy for both rural areas and urban and industrial sectors. The development of solar heating was one of the sources recommended for both sectors. With reference to rural areas, a section of a report [8] of the conference says:

> *The conference also urged acceleration of programmes for developing and using other new and renewable energy sources such as biogas, wind, solar, hydro, geothermal and peat where*

economically viable, so as to reduce pressure on fuel wood supplies and to improve rural living standards.

A solar water-heater project was recently completed in the Department. The heater employed a flat plate collector having an area of about four square metres ($4m^2$), and a storage tank of about 200 litres. A maximum mean water temperature of 68.5^0C and an efficiency of about 49% was achieved. Further work on the improvement of the heater and other forms of heaters is in progress.

Linkage Programme

In order to supplement the University's staff development scheme and the Departmental research opportunities, the Department along with other Departments of the Faculty of Science, is seeking linkages with other Universities and suitable institutions. When the Vice-Chancellor gave me the honour of representing him at the convocation ceremony of the University of Maiduguri held on 19th November,1981, I had the singular opportunity of meeting Professor Abdus Salam whom I have already mentioned before – as the 1970 Nobel Prize winner in physics for his unifying theory of "electro-weak" force. Professor Salam, as the founder and director of the renowned International Centre for Theoretical Physics, at Trieste, Italy, kindly agreed to consider establishing between his Centre and this Department, a Federation Agreement which would enable some of our staff to study for short periods at the Centre in Trieste. Our application is now before the Centre's Scientific Council. If, as I do hope, our application is successful, we hope, Vice-Chancellor, Sir, that the University will continue to support this move by entering into the agreement by which this University stands to gain.

With this discussion of our own local environment of teaching, research and staff development in the Department of physics at Ilorin, which is already familiar to may present here, my survey of the atmosphere of physics is completed.

3 PHYSICS OF THE ATMOSPHERE

3.1 General Features

From ancient times, man has discernerned the sky in relation to himself and his affairs. In biblical days, it was recorded in St. Matthew's Gospel, Chapter 16 verse 2:

> *When it is evening, ye say it will be fair weather because the sky is red.*

It is well known that our planet earth is unique within the solar system in having around it the envelope of air called the atmosphere. It is a protective envelope, like a blanket, shielding the earth's surface from the hazardous ultraviolet and x-ray radiations from the sun, and at the same time allowing the sun's visible and heat radiation to pass through, thereby maintaining the right climatic conditions for life on earth. It is well known that due to the nature of the gravitational field of the earth, atmospheric pressure falls off rapidly with altitude, or height. Consequently about 95% by mass of the atmosphere lies below the 25km altitude, and its normal composition, also by mass, is: nitrogen 78.0%, oxygen 20.8%, argon 1.0%, and the remaining constituents 0.2%. The remaining constituents which may be called the "minor" constituents are carbon-dioxide, hydrogen, ozone, the inert gases, and varying amounts of water vapour. Dramatic temperature variations occur with height in the atmosphere. I wish to relate a story connected with atmospheric temperature. During a government scholarship interview a candidate, when answering a question on physical geography said, *The higher you go, the cooler it becomes.*

Then instantly, a loud disapproval issued from one of the panelists who was a top government functionary. He declared the reverse statement,

The higher you go, the hotter it becomes.

Well, who was right? In relation purely to the atmosphere, they were both correct. It is true that, "the higher you go the cooler it becomes" up to a point, beyond which it becomes true that the higher you go the hotter it becomes. The change-over point in the atmosphere is called the tropopause, which in the tropics is at the height of about 17 km.

The structure of temperature variation mainly determines the division of the atmosphere into concentric shells, and their boundary layers. See Fig. 1. Starting from the earth's surface and proceeding outwards the divisions are the troposphere, tropopause, stratosphere, stratopause, mesosphere, mesopause, thermosphere, ionosphere, exosphere and finally the magnetosphere.[9] A little closer look at the atmosphere reveals that the atmosphere – earth unit functions, as it were, as an engine. It receives energy in the form of radiation from the sun, does work by generating winds and other waves, and gives off "exhaust" heat in the form of thermal radiation into space. See Fig. 2.

A balance between the incoming and outgoing energies is essential for the maintenance of steady general climatic conditions on the earth. Reference will be made later to this all-important energy balance.

The study of the atmosphere is very wide indeed. However, time will permit me to mention only a few of the most vital aspects and contributions by the home crew. These are tropospheric water vapour and radio-refractive index studies, ionospheric studies, atmospheric electricity and the Global Atmospheric Research Programme (GARP).

3.2. Water Vapour and Radio Refractive Index Studies

The study of the atmosphere as it relates to weather is called meteorology. This is a branch of applied physics which embraces the studies of weather elements such as pressure, temperature, humidity, winds and the resultant phenomena such as clouds, storms, rainfall, and other forms of precipitation. In order to facilitate weather predictions, these elements have to be measured at regular intervals and at world-wide networks of stations, not only on the earth's surface, but also at various heights up to the stratosphere. For upper-air measurements, in-situ methods using balloon-borne radio-sonde as well as remote sensing by ground-based radar are used.

Apart from weather considerations, the atmospheric conditions are of interest in other regards. To the astronomer the atmosphere is, in a way, a nuisance. This is because the air may scatter or absorb some of the precious few photons coming from whatever celestial body he is observing. It also affects the communication engineer who is concerned with the variations of the air's refractive index which may be such as to refract out of the desired path, or trap, **V.H.F.** and **U.H.F.** communication signals. The elements determining the radio-refractive index are air pressure, temperature and water-vapour pressure, the last element, water-vapour, being the one that is mostly responsible for the special variations which have the above undesirable effects. The undesirable effects of refractive index gradients is called "ducting". For instance, some workers at Ife [10] using some model tropical data, found that,

> *The percentage of time for which radio frequencies within the range 100 MHz are trapped are much higher in Dakar, Niamey and Fortlamy than in the stations Abidjan, Lagos and Banqui.*

For the purposes of refractive index studies and the north-south movement of the West African moist air front, I have for some years concerned myself with water-vapour studies. A high correlation has been found between the total precipitable water –vapour deduced from radio-sonde data and the absorption measurement [(11)] of solar radiation in 1.3 mm wavelength region. See Fig. 3. The absorption is due to the wings of the intense water vapour line 3_{-2} - 2_{-2} centred at 1.62 mm. Estimates of the total water-vapour content could therefore be made from such ground-based radiometric measurements. Working with surface and radio-sonde data from Niamey for a period of two years, equations of lines of regression have been derived [12] for estimating the total water-vapour content from water-vapour densities measured on the ground surface. Absorption measurements of solar radiation have also been made within the vibration – rotation absorption band of water vapour centred at the infra-red wavelength of 0.938 μm. [13] A method has also been outlined for deducing the total water-vapour contents from the water-vapour channel C3[14] and the "window" channel C4 of the Selective Chopper Radiometer instrument on Nimbus 5 satellite. Measurements and analysis of atmospheric radiation and water-vapour contents are continuing.

3.3 Ionospheric studies

The ionosphere, discovered by Appleton and Barnett in 1925, is a region of partially ionized air extending from about 60 km to the limits of the atmosphere in the van Allen radiation belts. It is well known that radio waves are reflected from the various ionospheric layers, a process which makes possible long-distance radio-communication. The Department of Physics, University of Ibadan has established an international reputation [15] in ionospheric studies. The activities, begun there about 1952, are continuing in the measurements of the variations in ionospheric electron densities, irregularities, drifts[16], layers' heights, the electrojet and their correlations with geomagnetic variations. A direct application of the studies is the possible predictions of radio wave absorption[17] in the various ionospheric layers. Research in this field has also begun in this Department.

3.4. Atmospheric Electricity

It has been known for a long time that there is a persistent electric field in the air above the earth during fair weather. Its magnitude is about 240 volts per metre and its direction is such that the earth carries a negative charge and the upper layers of the air a positive one. This field produces a downward 'leakage' current which, though having a small value per square metre, amounts to over 1000 amperes. This current would, however, discharge the air-earth capacitor in a very short time, unless it is re-charged. Some workers in Zaria have shown that when a severe Harmattan is blowing, the fair weather electric field near the ground may become reversed, indicating that the Harmattan dust is negatively charged relative to the earth. See Fig. 4.

As thunder clouds carry large electric charges, the electric field between their bases and the earth may be as high as 1,500 volts per metre, and a lightning flash may occur when the field reaches about 10,000 volts per metre. It is known that a single cloud-to-earth lightning flash may pass up to bout 10,000 amperes of current for about 2 millieconds. It has been shown at Ibadan [7] that,

> *On a global scale, thunder clouds are capable of generating at least 1,300 amperes of current, which is just about the right amount of current required to balance the downward 'leakage current' known to flow in all fair weather areas of the earth.*

3.5 Global Atmospheric Research Programme (GARP)

The international global experiment GARP [18] has been launched in order to make the necessary comprehensive measurements required for the numerical modeling of the atmosphere for climatic prediction purposes. For the experiment, the following measurement specifications are required:

Atmospheric State Parameters	**Accuracy(RMS error)**
Wind components	± 3 m s $^{-1}$
Temperature	± 1 K
Pressure at reference level	$\pm 0.3\%$
Water-vapour pressure	± 1 mb
Sea surface temperature	± 0.2 K

The programme [18] stipulates the following:

> *Measurements of these parameters (above), (or their deduction from observations) are required every 12 hours, with at least one measurement every 100 km in the horizontal and at least eight data levels in the vertical (surface, 900,700,500,200,100,50 and 20 mb). Information is also required on precipitation, cloud cover, surface conditions (e.g. snow or ice cover) and elements of the radiation budget.*

In order to realize these objectives, the network of surface and radio-sonde measurement stations have been augmented by the meteorological satellite measurements such as the Tiros, Nimbus and Meteosat series. The great advantage of a satellite as a measurement platform is that good coverage in space and time can be obtained. See Fig. 5. From a geostationary satellite, orbiting at 35,000 km altitude so that it remains directly above a fixed point on the equator, continuous observation of about a quarter of the atmosphere is possible. A polar orbiting satellite such as Nimbus or Tiros in a circular orbit at about 1000 km altitude makes about fourteen orbits per day and can view all parts of the atmosphere at least twice a day.

Each of such satellites carries on board a number of independent experiments or measuring instruments. Among the instruments on board Nimbus V, launched in the U.S.A. in December 1972, are the T.H.I.R. (Temperature Humidity Infra-red Radiometer) and the S.C.R. (Selective Chopper Radiometer) [19]. See Fig. 6. The former is an infra-red imaging system for various temperatures of areas in the field of view to be shown in fourteen different shades of gray. The SCR has 16 channels which have such filters that the channels effectively receive radiations from different depths in the atmosphere, thus making three-dimensional measurements [20] of the atmosphere possible.

3.6 Minor Atmospheric Constituents

The effects of certain minor atmospheric constituents are important to the radiation budget and climatic conditions. Their importance is perhaps comparable with the disproportionately great importance of minority ethnic populations in politics. Having already given adequate coverage to water-vapour, I wish to mention briefly the roles of ozone and carbon-dioxide. See Fig. 7.

Ozone occupies a layer of the atmosphere centred at the stratopause which is at about 50 km altitude. The gas is formed through a photochemical reaction between ultra-violet light and oxygen. As ozone has a very strong absorption band in the ultra-violet wavelength region of 200–300nm, most of the ultra-violet component of solar radiation is absorbed in the ozone layer where it has two important effects. Firstly, the absorption of energy is responsible for the rise in temperature around the stratopause. Secondly, the layer shields the surface of the earth from the intensive and hazardous ultra-violet rays of the sun.

Unlike ozone which is concentrated in a layer, carbon-dioxide is uniformly mixed throughout the atmosphere. Its strongest absorption band occurs at the wavelength of 15μm, which happens to be the wavelength region where terrestrial radiation is maximum for the earths mean temperature of about 300 K. Carbon-dioxide is therefore commonly used in absorption cells in the Selective Chopper Radiometer [18]. It is to be noted that a significant increase in the carbon-dioxide content of the atmosphere would produce a change in the mean temperature of the atmosphere and therefore in the general climate of the earth.

4 CONCLUSION

I have outlined a view of the development of the main ideas of physics and the activities within the Department of Physics of this University. Lying within our control is the atmosphere of our class-rooms and laboratories Jearl Walker[21], the author of a popular book entitled "The Flying Circus of Physics" maintains that the teaching of physics, which is the subject at the core of all natural science, should never be dull. In his attempt to teach to young people the principle of "pressure = force per unit area", he would demonstrate lying bare-bodied on a bed of nails. His students saw, and could never forget, that he was not hurt because the nails were so many that the force exerted by his body weight on any one nail, was too small to pierce his skin. Another teacher would demonstrate the conversion of energy from one form to another using a 'solar cube': light energy $\rightarrow$ to electrical energy $\rightarrow$ to mechanical energy of motion. (Give practical demonstration with a flash light and a 'solar cube' at this point during the lecture).

I have also presented an outline of the application of physics to the study of the atmosphere. We have seen, to some extent, what the atmosphere does for us in supporting life on earth. However, one is mindful that the cigarette or pipe smoker deliberately tries to modify the atmosphere around himself. Large industries belching smoke, force a change of atmosphere on the inhabitants in the neighbourhood. The question should then be asked, "What are we doing to the Atmosphere ?".

We in Nigeria know that the Sahara desert is encroaching on our northern doorsteps. Reports have shown that many countries in the mid and high latitudes of the northern hemisphere have just gone through their worst winter for over fifty years. Whether or not significant climatic changes are taking place, is not certain. What is certain is that the changes in the optical and infra-red reflectivities of large portions of the earth surface, due to physical replacement of vegetation by concrete, asbestos and the like, and the enormous quantities of carbon-dioxide from automobile and industrial fuel combustions, are likely to alter the radiation budget of the earth. See Fig. 8.

I therefore wish to make the following recommendations to the University and the Government:

(i) The University should increase its effort in providing the time and facilities which physics staff need to create and maintain the right atmosphere of progress in the class-room and laboratories. The time should be provided through adequate staffing, and the facilities through funding, materials and sites for observatories. Future Nigerian Abdus Salams must not be missed !

(ii) The Government should support the programmes at local and international levels for monitoring atmospheric conditions especially changes in the concentration of ozone in the stratosphere, and changes in radiative transfers as affected by carbon-dioxide.

(iii) Government should check, through legislation and other necessary means, atmospheric pollution by industries and other agents.

(iv) Government should step up its programme of aforestation and re-forestation in order to restore the natural balance between the oxygen and carbon-dioxide contents of the atmosphere, and hence the natural radiative balance. In this regard, this University should show good example by ensuring that any area at the permanent site which is not built with structures or roads is green with grass or trees all the year round.

With these recommendations, Sir, I hope that the atmospheres will be right for future generations trained here to succeed in advancing the frontiers of physics and in maintaining the natural environment on which so much of the quality of human life depends.

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