UNIVERSITY OF PORT HARCOURT

"THE LINE IS GONE OUT THROUGH ALL THE EARTH"

An Inaugural Lecture

By

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DEDICATION

Firstly, this work is humbly and reverently dedicated to Him who by himself alone created the Universe/ the Heavens and the earth out of nothing but by His spoken words alone - "Let there be light “and there was light.

Secondly, the work is dedicated to the memory of my late Husband Venerable Professor T. N. Okujagu, who God used to channel me into the academic field from my former place of work, The Department of Meteorological Sciences, of the Ministry of Aviation.

Thirdly the work is also dedicated to the Utong Royal Family of Ilotombi presently led by His Royal Highness, Chief Abraham B. Utong X, for producing the first female Professor of Physics in Andoni and in Rivers State.

ACKNOWLEDGEMENTS

Mr. Vice Chancellor Sir, My lecture will not be complete today without acknowledging the Almighty God, my creator, sustainer, Healer, Deliverer and Saviour, and the Human Angels and Agents he placed on my way to assist me in this journey of life up to this point in time. This acknowledgement is presented not necessarily in order of their importance and impact in my life, but is presented chronologically, as my life progressed.

The first on the acknowledgement list is my late mother, Madam Lily Ete Utong, who brought me into this world, and who after the death of my father at a tender age of only two, did all she could to sustain us (Me and my siblings) and led us in the ways of the Living God. May her righteous soul rest in the bosom of her Lord, who she served diligently while here.

Today I stand to sincerely thank my elder sister Mrs. Naomi Israel Etete, who immediately after my father's death, stepped into his shoes and became the man of the house, and took me from my mum to her teaching station after the death of my immediate elder and immediate younger sisters which happened in quick successions and close to my father's death. From this time, God used her to give me a head start in academics as she enrolled me in school. May God bless you abundantly? When she eventually got married, her husband Mr. Israel Etete became the male father-figure in my life. I therefore acknowledge my present parents Mr and Mrs Israel Etete (Mma Mma and Sir Sir). Without your efforts and input in my life in those early years that became the sure and solid foundation on which I stand today as a professor of Solar Energy Physics, I would have definitely ended like most of my mates and contemporaries in the village as a nobody or at best would have Just ended in Standard six like a few of them who managed to get to that "Exalted point" in those days. Your belief in and love for me made you to push me up to the secondary school level.

My two other siblings Mr. Clinton I. Z. Utong and Mr. Christian A.Z. Utong, I acknowledge your contributions in my life. Mr. Clinton Utong as a typist was always available to type all my project manuscripts throughout my academic pursuit. From my B.sc project, M.sc deserts two to my Ph.D. thesis where all typed and prepared by him, Papa Choba as we all call you, I am very grateful. Mr. Christian Utong is one that God uses to stand me at the most critical and crucial times in my life on issues that set me in the part God intends for me. God bless Papa Ogwu ama.

I also acknowledge my late Uncles who were used by God to build me up in various ways. My Uncle, late Mr. Johnson Ete-ubong who gave me a name (Awaji-Igobom –Chosen by God) that has influenced my walk with and work for God). Since I was small till now I say 'Thank You'. Late Chief B.E Utong, the Okan-Ama, Ilotombi the (VIII), who ensured that every child born to the Ekechackmkpa and Ete Utong family went to school and encouraged the training of my Elder Sister, Mrs. Naomi Etete (Who in turn became and is instrumental to the education of not only me but indeed all children born to this family and their posterity), I say your memory is blessed.

Mr. Randolf Etete Utong who God used to sustain the rest of the Ekechakmkpa and Ete Utong family, when they returned home after the Biafra war with nothing, your memory is really blessed. To my loving pragmatic, Indefatigable, clergy and academic erudite husband, Late Venerable Professor Thompson Ngeri Okujagu, the man who God used to channel

me into the academic profession and for sharing my vision and burden for souls, I say your name have been immortalized through me and our children. Your memories inspire me to greater heights and I am really proud of you for taking after us. Your future is bright and you will excel in your chosen fields.

I now wish to acknowledge the individuals that I met on my journey through the academics ladder, I met several people who have assisted me immensely.

The first group I will like to acknowledge are the group of the missionaries of the Scripture Union and Sudem Interior Mission namely; (Rev. and Mrs. Brown –My B.K-Bible knowledge, in form 3 and 2 respectively as it was called in those days and my Christian parents, Mr. and Mrs. Rideout (My Physics teachers In form 4 and 3 respectively and our Scripture Union Coordinator and Miss. Mosbey (My Biology teacher in form 2 and 3). Late Mrs. Mary Rideout was the one whose method and manners of teaching physics so fascinated me and made me fall in love with and hooked unto the Subject/course Physics. I like the simple way Late Mrs. Anita Brown handed Bible knowledge and her friendly disposition to me paved the way for me o give my life to Christ in form 3 in **1971**. To these two women, I respectively owe my becoming a physicist (Mrs. Mary Rideout) and my Christian life and growth (Mrs. Anita Brown) may their memories be blessed.

My principal in B.M.G.S. Bori Mr. V. G Chinwa who was my math's and English teacher and also the moral power whose words and counsel, instilled true discipline in me and all his students, I say you were indeed a strong hammer that hung over our heads to ensure we complied to all rules and regulation of the school. You are highly acknowledged.

The next group of people I want to acknowledge are

accomplished academics that is made up of my supervisors namely; my B.sc supervisor, prof. SK Adjepong (a Ghanaian) my M.Sc dissertation supervisor prof. B.J Omotosho and my Ph.D dissertation supervisor, Prof. C. E. Okeke. These were kind men whose interest in my work spurred me to be my best.

My other lecturers Prof. Evwaraye Ofoegbu, Ocockera, Ayibaemi Spiff and others deserve acknowledgement and my mates prof. I.O Owate and Prof. Rose Osuji, and my colleages in the department of physics Uniport, Prof. Ebeniro, Ekine, Prof. Abumere, Prof. Akwiri, Prof. Chukwuocha, (the present Dean of the faculty of science) Dr.(s) E. Osarolube, P. C. Ononugbo, E. Ehirim, A. Sofolabo, Y. Chad Uniorem (the present HOD, Physics), Ikot, Ngiagias, and others who have maintained a family spirit in the department. Also acknowledged are my cherished academic mentors namely; Prof. Onogfeghara, Prof. S.N. Okiwelu, Prof. Ayibaemi Spiff, Prof. Okoli and my friends Prof(s). Nnenna Frank Peterside, Toru Hart, Eka Nwokoma and Awaii Waadu. Majority of those who have made my journey worth the while are my students at all levels from the department of physics, University of Port Harcourt and in Rivers State University and Federal University Otuoke where I did my sabbatical in 2010 and 2017, respectively both the students at these two institutions are hereby acknowledged.

My Ph.D and M.sc students especially those I supervised (Drs. Usoh, Elalah, Ewurum, James, Edebatu, and Nwokocha, Messis Williams, Abraham, Igbudu, Njan. Those I am supervising are all parts of what I am preparing today.

My spiritual Fathers and friends, Apostle G.D. Numbere, Rt Rev. Onyukwu and Mrs Chinyere Elenwo, Rt Rev. and Mrs T.R. Abere, and Rt Rev and Mrs O.N. Nwankpa, Ven G.G.

Hart, Rev Can O.R. Sunday, Mr and Mrs Mike Mon, Dr and Mrs Samuel Erenike, Dr and Mrs Aaron, and the entire Divine Anglican Church family are all part of today's success story, Others are Ms. Koripamo my principal as a young teacher in Marian High School Bane, after my secondary school education my late friend Dr Mrs Bridget Birabi and her husband Dr. B. Birabi, My Doctor(s) Dr. A. Okilo, Dr. Prosper Igboeli and his daughter Doctor Prof. Chinyere Igboeli who God used to ensure that I am still breathing on this side of eternity in the three occasions when I had close shores with death, but for their expertise and the Grace of God when i went through a very difficult and life threatening mastectomy (in 2005) and mamectomy (in January and June 2016) that saved my life from final stage breast cancer.

I must also acknowledge two families of the Okujagu of Okujagu-Ama and the Utong royal family of Ilotombi Ancient Town (Andoni LGA). Finally I acknowledge Mr. Christian Nuka Giomi and his team who are busy ensuring that my vision of helping the less privileged to find relevance through the free skill Acquisition is the Ven. Prof. T.N. Okujagu Foundation For Ethics and Learning (O' foundation) is sustained even though I am busy with other frons such as this.

ACRONYMS

ORDER OF PROCEEDINGS

2.45P.M. GUESTS ARE SEATED

3.00P.M. ACADEMIC PROCESSION BEGINS

The procession shall enter the Ebitimi Banigo Auditorium, University Park, and the Congregation shall stand as the procession enters the hall in the following order:

ACADEMIC OFFICER
PROFESSORS
DEANS OF FACULTIES/SCHOOL
DEAN, SCHOOL OF GRADUATE STUDIES
PROVOST, COLLEGE OF HEALTH SCIENCES
LECTURER
REGISTRAR
DEPUTY VICE-CHANCELLOR [ACADEMIC]
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
VICE CHANCELLOR

After the Vice-Chancellor has ascended the dais, the congregation shall remain standing for the University of Port Harcourt Anthem.
The congregation shall thereafter resume their seats.

THE VICE-CHANCELLOR'S OPENING REMARKS.

The Registrar shall rise, cap, invite the Vice-Chancellor to make his opening remarks and introduce the Lecturer.
The Lecturer shall remain standing during the Introduction.

THE INAUGURAL LECTURE

The Lecturer shall step on the rostrum, cap and deliver his Inaugural Lecture. After the lecture, she shall step towards the Vice-Chancellor, cap and deliver a copy of the Inaugural Lecture to the Vice-Chancellor and resume her seat. The Vice-Chancellor shall present the document to the Registrar.

CLOSING

The Registrar shall rise, cap and invite the Vice-Chancellor to make his Closing Remarks.

THE VICE-CHANCELLOR’S CLOSING REMARKS.

The Vice-Chancellor shall then rise, cap and make his Closing Remarks. The Congregation shall rise for the University of Port Harcourt Anthem and remain standing as the Academic [Honour] Procession retreats in the following order:

VICE CHANCELLOR
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
DEPUTY VICE-CHANCELLOR [ACADEMIC]
REGISTRAR
LECTURER
PROVOST, COLLEGE OF HEALTH SCIENCES
DEAN, SCHOOL OF GRADUATE STUDIES
DEANS OF FACULTIES/SCHOOL
PROFESSORS
ACADEMIC OFFICER

PROTOCOLS

- The Vice-Chancellor
- Previous Vice-Chancellors
- Deputy Vice-Chancellors (Admin and Academic)
- Previous Deputy Vice-Chancellors
- Members of the Governing Council
- Principal Officers of the University
- Provost, College of Health Sciences
- Dean, Graduate School
- Deans of Faculties
- Heads of Departments
- Distinguished Professors
- Directors of Institutes and Units
- Visiting Academics and Colleagues
- Esteemed Administrative Staff
- Captains of Industries
- Cherished Friends and Guests
- Unique Students of UNIPORT
- Members of the Press
- Distinguished Ladies and Gentlemen.

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PREAMBLE

My journey into the field of Solar Energy Physics Mr. Vice Chancellor sir, it is important to narrate the story of my unplanned journey into the field of Solar Energy Physics as this will assist in the understanding the lecture. This story is sub-divided into subheading as follows;

THE NEVER TO BE "INDUSTRIAL ENGINEER"

After the civil war in 1970, my elder sister got me enrolled in BMGS Bori into class two to continue my secondary school education that was interrupted by the civil war in 1967. I found myself in class A in form three having taken third position in the final exams in class B where I was registered in form two when I joined the school. Here in class A, I was the only girl with the rest 34 students as boys. This being the case I took up the challenge to compete with them. At that time five of us to top the class with each of us working hard to top the class and you never dream of having the monopoly of staying at the top at all the time without a change.

The five of us (four boys and one girl) dreamed of going to the US and UK after having our certificate to read Industrial Engineering so that we can come back and build industries in Nigeria(Rivers state specifically) by some turn of events and for no obvious reason I was denied scholarship(even with my better result than some of the boys) , the four boys travelled out of the country for further studies, while I was left behind. I felt like a failure and I lost the steam of going further but rather picked up a teaching job at Mariam High School Bane, (for three years) and was subsequently transferred Government Secondary School Ngo, Andoni (for 1 year) as Physics Math's and Chemistry teacher. I grew to love this job which enabled me to impact knowledge to the younger generation. After four good years of this teaching job I finally gained admission into the newly established university of Port Harcourt as one of the pioneer students of this unique university to read the only subject (Physics) that I felt was closest to Industrial engineering as there was no Industrial Engineering or any course in Engineering available then in Uniport neither in any University in Nigeria at that time. I had no problem enrolling with Physics as Physics was my best subject in secondary school.

After my Graduation and NYSC I was employed by COE (now IAUE) as a physics lecturer but that sojourn was short-lived as I left the institution for a Federal Government job whose interview I attended during NYSC as a meteorologist. On reporting to the ministry of meteorological services of the ministry of aviation for the employment, I was immediately sent to do my master's degree in meteorology at the University of Ibadan (UI) which again turned me away from my ambition of being an Industrial Engineer, no to an Atmospheric Physicist.

As God the one who has been directing my affairs so far, would have it, after my graduation and brief work at the Ministry of aviation, I finally found myself in the employment as a physics lecturer at my alma mater the University of port Harcourt from 1985 to the present which represent the final turn away from the Industrial Engineer that I badly wanted to be.

THE SOLAR ENGINEER PHYSICIST

In my final year, projects topics were posted on the notice board and we were asked to choose any topic of interest from those available topics. By whatever it was, I took interest in two topics, namely Bubbles and flat plate collector because these two topic were never taught to us during our lectures, shut out of mere curiosity I decided to choose that of flat plate collector, wondering what kind of plates they were and what they would be collecting. Although the topic Bubble seem attractive to me; Having chosen the topic which was subsequently approved for me, I quickly dashed to the library to find out what it was all about but found no clue I then dashed to CST (now UST) Library that been an older school, to make further search. There I stumbled into some journals that gave me both the clue and insight into the topic. I was surprised to find out that, that plate collectors are devices that is used to convert solar energy into heat energy to heat water.

I was again transferred to PRODA, in Enugu where some work was been carried out on these collectors. Immediately travelled to Enugu to PRODA. There my fascination about these devices were widened and in no time I was able to construct and test a simple flat plate collector at an Equatorial location, a work which was published in the journals of solar and wind technology(an international journal). So Mr. Vice chancellor sir, as you can see, as far back as 1980, as an undergraduate student began my journey into the field of solar energy and on my way of becoming a solar energy scientist which I am today.

After joining the staff of physics department in 1985, I was nominated by prof. Ofoegbu, a then HOD for a month workshop on solar energy at Treste, Italy in 1987, which further helped to entrench me in the field of solar energy physics. At that time I became interested in the area of solar radiation studies as directed from my first degree supervisor prof. S.K. Adjepong (a Ghanaian who had gone back to Ghana) when we met at Trieste.

By the time I was due to go for my Ph.D. , I found that the University of Nigeria Nsukka was offering both M.Sc., and Ph.D. in meteorology was not present in Uniport or UI where I well initially planned to do my Ph.D. Due to my interest in solar energy physics, I opted to go to Nsukka for admission. I wrote my Ph.D. admission proposal interview on solar radiation in Nigeria. Based on this I was admitted but when I went to start my work my supervisor Emeritus professor C.E. Okeke who was also the HOD who admitted me on my proposal, refused to supervise in on that topic but rather asked me to go and search for another topic that he will be willing to supervise me. My search pull me into the area of solar energy materials with the topic Solar selective surfaces for Energy Application: As we can see through this story, I believe that the hand of Him who created the universe and made it Tabernacle of the sun, whose lines have gone throughout all the world and made nothing to be hid from the heat thereof have truly guided every step into this special field of study. He has also guided my eyes to see my ears to hear my body to feel and my intellect to understand the awesomeness and the marvelousness of His wonderful creation.

INTRODUCTION

Mr. Vice Chancellor sir, as we have seen my academic journey has taken me through different areas of physics as follows;

First Degree	-	General Physics
Second Degree	-	Meteorology
Third Degree	-	Solar Energy Physics

Over the years my work has therefore spanned these areas of physics and I have found myself teaching and supervising in the area of solar energy and solar energy devices, Atmospheric physics and meteorology, Environmental physics and radiation, material science and solar energy materials. Sometimes I used to wonder how all these different areas are related and whether indeed these areas can be pulled together, and further still how would I be able to write a single meaningful inaugural lecture from all these areas of physics. This has been part of my dilemma that has kept me thinking and also shrinking from presenting my inaugural till now. As the elders say "wisdom comes with age" and the more you are involved in something, the more you understand the thing.

This is why I can make boldly today to be able to present an inaugural lecture with a single topic through which every area of my research (solar energy physics, meteorology, atmosphere and environmental physics and solar interaction with materials) are interwoven and presented ‘As a bride coming out of his chambers and a strongman to run the race”. The topic is lifted from the Bible precisely Ps.19:5. Lecture is not a sermon or religious discourse but a scientific one. Permit me Mr. Vice Chancellor Sir, to quote this verses of scripture directly from the Bible and I quote:

Psalm 19:1-6 - A Psalm of David

1. *The Heavens declare the glory of God and the firmament sheweth His handiwork*
2. *Day unto Day uttereth speech and night unto night uttereth knowledge*
3. *There is no speech nor language where their voice is not heard*
4. *Their line is gone out through all the ends of the earth and their words to the ends of the world. In them hath He set a tabernacle for the sun*
5. *Which is as a bridegroom coming out of his chambers and rejoiceth as a strong man to run the race.*
6. *His going forth is from one end of the heaven, and His circuit unto the ends of it; and there is nothing hid from the heat thereof.*

This scripture has actually described the sun and the solar which is a part of the firmament and galaxies. In a nutshell, this is a key to the standing of the various research endeavors. I have therefore organize this lecture along the four parts according as follows:

1. The heavens and the firmaments- In Him he has set a tabernacle for the sun(vs 1-4)
2. The Sun and the Solar system: A bridegroom coming out of His chamber (vs a)
3. Solar radiation and sunshine their line is gone as a strong man ready to run the race.
4. Solar manifestations - His going forth is from one end of the heaven and His circuit is unto the end of it (vs 6a, b)
5. Solar radiation interactions - And nothing is hid from the earth thereof. (vs 6b)

1. THE HEAVEN AND THE FIRMAMENT: A TARBERNACLE FOR THE SUN

Mr. Vice Chancellor Sir, The heavens in this scientific discourse is used to mean the sky or space and the firmament of the universe means the celestial sphere which connotes the idea of being fixed space. Biblically, the heaven and the firmament mean the structure above the earth atmosphere, which God the creator used to separate the "waters above "the earth from expansion or vault or arch of the sky. Infact God called the firmament heaven as part of the cosmic design (Gen. 1:6-8). This expanse and arch of the sky is commonly referred to as the expressing Gen 1:14-18 And God said, let there be light in the firmament of the heavens to divide the day from the night and let them be for signs and for seasons and for days and for years, and let them be for light in the firmament of the heaven to give light upon the earth and it was so. And God made two great lights; the greater the (sun) light to rule the day, the lesser the light (moon) to rule the night. He made all the stars also. And God set them in the firmament of the heaven to give light upon the earth, and to rule over the day and over the night, to divide the light from the darkness, and God saw that it was good. This is why God created the heavens and the firmament as a tabernacle for the sun and by extension the moon.

Hence the sun and everything that orbits it (i.e. the solar system) is located in the Milky Way Galaxy. Truly God has made the heavens and the firmament (the Galaxies) A Tabernacle (dwelling place) for the sun. A Galaxy is a gravitationally bound system of stars, stellar remnants, interstellar gas, dust and dark matter that make up the universe. Ma such assemblages are very enormous and some certain hundreds and billions of stars. Galaxy is Greek word meaning ‘‘milky’’ giving rise to the name The "Milky Way".

The Energy produced in the core powers the sun produces the heat and light that the sun emits. The energy from the core is carried outwards by radiation (electromagnetic radiation) which bounces around the radiative zone taking about 170,000 years to get from the core to the top of the convective zone.

(ii) The Radiative Zone: This is the solar interior just outside the core and is between the innermost core and the outer convective zone. In the radiative zone, energy generated in and released by the core moves outward as electromagnetic radiation that are controlled by photons at extremely slow velocity through the zone. In this zone particles of light can only travel for a few millimeters before they hit another particle, get absorbed, and then released, then gets absorbed and released as using approximately about 1035 absorptions and re-emissions takes place in this zone before photons reach the surface. Here it takes about 170,000 years before a photon gets to the top of the convective zone. The suns radiative zone extends from the core outward to about 70% of the sun's radiation. When the energy reaches the top of the radiative zone, it begins to move in a different fashion into the convective zone.

(iii) The Convective Zone: The convective zone is also called the boiling zone. In the convective zone there are large bubbles of hot plasma (a soup of ionized gaseous atom) that move up. Heat and energy are carried out along with matter in a swilling flows called convective cells. This motion is similar to the rolling flows seen in a pot of boiling water. The zone extends from a depth of 200,000km to the visible surface of the sun. In this region, energy is transported by convection. The surface of the convective zone is where light is created. The inner parts of the sun (core and radiative zone) spin differently from the outer layers (convective zone) The boundary of these two types of motion, which has between the radiative and convective zone is called the tacholine.

(iv) The photosphere: The photosphere is the lowest layer of the solar atmosphere. It is essentially the solar surface that we see when we look at the sun in "white" (i.e. regular visible or visible) light. Features like sunspots and faculate (bright little cloud-like feature) are usually observed in the photosphere. This zone is a 300 mile thick and 500 kilometers thick region from which most of the suns radiation escape outward. This is not a solid surface like the earth surface because it is made up of gaseous elements. It is marked by bright bubbling granules of plasma and darker cooler sunspots, which emerge when the suns magnetic field break through the surface.

The photosphere is also a source of solar flares (tongues of fire that extends hundreds of thousands of miles above the sun's surface). Solar flares produce burst of electromagnetic radiation, x-rays, ultraviolet radiation, visible light and radio waves. The surface of the sun, the photosphere is a 300 mile thick (500- kilometer thick) region from which most of the suns radiation escapes outward. This is not a solid surface like the surface of other planets like the earth, instead this is an outer layer of glassy stars.

(v) The Chromosphere: Above photosphere is the tenuous chromosphere. The chromosphere emits a reddish glow as super-heated hydrogen burns off. The red bim can only be seen during a total solar eclipse. When the sun, the moon, the photosphere, the chromosphere looks like a red rim and at other times, light from the chromosphere is usually too weak to be seen against the brighter photosphere.
The photosphere may play a role in conducting heat from the interior of the sun to its outermost layer, the corona. Certain kinds of seismic waves is seen channeling upwards into the lower atmosphere of the sun called the chromosphere and from there into the corona, and may form part of the wave that contribute to the energy of the atmosphere of the earth.

THE CORONA: The corona is the last and outermost layer of the sun. It is usually not visible ordinarily, except during total solar eclipse when it appears like a beautiful while crown with plasma streamers narrowing outward, forming shapes that look like flower petals that flows outward into space.

PROPERTIES OF THE SUN:

(I) Solar Granulation

The surface of the sun, like the surface of a boiling pot is constantly changing. The cell structure or bubbly look of the photosphere is what is referred to as granulation. The boiling nature of the sun allows heat from the core to be brought up through the convection zone and into the photosphere, just like heat from the bottom of a pan ends up heating the entire content and the air above it.

(ii) Solar Wind

The sun releases stream of particles and magnetic fields called the "Solar Wind". The solar wind slams the planet across the solar system with particles and radiation- which can stream all the way to planetary surface unless thwarted by an atmosphere, magnetic field or both these particles interact with a few planets and other celestial bodies (see below).

(iii) Solar Heliosphere

The heliosphere is the bubble created by the solar wind- a stream of electrically charged gas blowing outward from the sun in all directions. The boundary interstellar gas called the termination shock. This edge occurs 80-100 astronomical units. Hence the heliosphere doesn't extend quite so far away from the sun, and describes the volume of space controlled by the sun's magnetic field.

(iv) Solar Orbital and Rational Dynamics

The sun and everything that located in the Milky Way galaxy. Our solar system is moving with an average velocity of 450,000 miles per hour (720,000 kilometer per hour). But even at this speed it takes us about 230 million years to make one complete orbit around the Milky Way.

The sun rotates at its orbit the center of the Milky Way. It spins has an axial tilt of 72.5 degrees with respect to the plane of the planet orbit.

Since the sun is not a solar body, different parts of the sun rotates at different rates (i.e. exhibits differential rotational dynamics). Thus, the outer layer of the sun exhibits different rotations depending on the point of the earth that is involved. For example, At the equator the surface of the sun spins (rotates) once every 25-25.4 days. Near the poles the sun spins or rotates once on its axis as much as every 36 days giving an average of 30.5 days of rotation. This differential rotation extends considerably down into the interior of the sun, but the core of the sun rotates as a solar body. The odd differential behavior of the sun and all other gas planets is due to the fact that the sun is not solid like the earth, but is made up of gases.

(v) Solar Magnetosphere

The electric currents in the sun generates a complex magnetic field that extends out into space to form inter planetary magnetic field. The sun's magnetic field is carried throughout the solar system by the solar wind- a stream of electrically charged gas blowing in all directions. Since the sun rotates the magnetic field spins out into a large rotating spiral known as parker spiral.

As magnetic field becomes more complex, it releases and explodes energy near the solar surface. The solar explosions can take the form of solar flares, coronal mass ejections or release of incredibly fast charged particles that race out from the sun at nearly the speed of light.

The sun doesn’t behave the same way all the time, but goes through phases of its own solar cycle. Approximately every eleven (11) years, the sun's pole change their magnetic polarity. When this happens, the sun's photosphere, chromosphere and corona undergoes changes from quiet and calm to violently active. The height of the sun's activity known as solar maximum, is a time of solar storms: sun spots, solar flares and corona mass ejections. These are caused by irregularities in the sun's magnetic field and can release huge amounts of energy and particles, some of which reach us here on Earth. The space weather can damage satellites, corrode pipelines and affect power grids. (April 25, 2019).

(vi) Solar proximity to the Earth:
The distance between the sun and the earth changes during the year due to the rotation of the sun and that of the earth about the sun. At its closest, the sun is 91.4 million miles (147.1 million km) away from us. At the farthest, the sun is 94.5 million miles (152.1 million km) away.
Our planet earth is the third planet from the sun, in the solar system, hence the sun appears very much larger and brighter than other planets because we are very close to it.

(vii) Solar Mass:
The sun contains most of the mass in the solar system. It makes up about 99.8% of the solar system, while the other planets in this system Earth, Venus, Pluto etc.) of the solar system have mass of only about 0.29% of the total mass of the solar system.

CHARACTERISTICS OF THE SUN

A. Orbital characteristics	Value
* Mean distance	2.7 X 10^{17} Km
* From Milky Way core	27,700 light years
* Galactic Period	2.25 - 2.501 X 10^{8} years
* Velocity	220km/s (orbit around the Milky Way)

20km/s (relative to average velocity of other stars in Steller news bourhood)
370km/s (relative to the cosmic microwave background).

B. PHYSICAL CHARACTERISTICS

* Equatorial Radius	695,342km (432,168.6miles)
* Equatorial Diameter	109km X Earth (332.946 mile X Earth)
* Equatorial Circumference	1,390,000km or 1.390 X 10^7km
	4.379 X km
	109 X Earth
* Flattening	9 X 10^{-6}
* Surface Area	6.09 X 10^{12} km
	12,000 X Earth
* Volume	1.41 X 10^{18} km
	1.3 X 10^6 X Earth
* Mass	1.9885 X 10^{30}kg
	333,000 X Earth
* Average Density	1.408g/cm
	0.255 X Earth
* Centre Density (Modeled)	162.29km^3
	12.4 X Earth
* Equitoral Surface Gravity	274m/s^2
	28 X Earth
* Moment of Inertia factor	0.072 (Estimate)
- Escape Velocity	617.7km/s
- (from the surface)	55 X Earth
* Distance from the earth	93 million miles (150 million km)
* Temperature (center/core) (modeled)	1.57 X 10^7km
- Photosphere (surface-effective)	57772km
-Corons	55800 X 10^6km
* Lumino (L_{sol})	3,828 X 10^{26}W
	3.75 X 10^{28} Lm
	98 Lm/W/efficiency
* Color (B-V)	0.63
* Mean Radiance (L_{sol})	2.009 X 10^7 W.m^{-2}Sr^{-1}
Age	4.6 billion years

C. Rotation characteristics

* Obliquity	7.25 (to the ecliptic)
	67.23 (to the gatactic plane)
* Right ascension of the North pole	286.13
	63.52 North

Sidereal rotation period	25.05 d
(at equator)	25.38 d
(at 16 Latitude)	25 d 9h 7min 12s
(at poles)	34.4 d
* Rotational Veloatry (at equator)	7.189 X 10^3km/h

D. PHOTOSPHERIC COMPOSITION BY MASS

Hydrogen	73.46%
Helium	24.85%
Oxygen	0.77%
Carbon	0.29%
Iron	0.16%
Neon	0.12%
Nitrogen	0.09%
Silicon	0.07%
Magnesium	0.05%
Sulphur	0.04%

3.2 THE RACE TO THE EARTH'S ATMOSPHERE

As solar radiation travels out from the central core towards the surface of the sun, the energy of the sun is continuously absorbed and re-emitted at lower power so that by the time it reaches the sun's surface, it is primarily a visible light (sunlight). For the last 20% of the way to the surface, the energy is carried by convention (in the convention zone), rather than by radiation. From the corona to the surface of the earth through the earth’s atmosphere, the energy is conveyed again by radiation.

Radiation from the sun's photosphere is seen on the earth as sunlight just 8 minutes after leaving the sun. This shows the great velocity with which light travels. This is what is known as the' speed of light' which is known as $3x10^8$ meter per second ($3x10^8$m/s.) This radiation is on the earth's surface as sunlight which propagates or radiates through vacuum without any physical medium or matter and has the following features:

1. Carries and provide light that illuminates the earth and gives warmth to the earth's atmosphere and surface that makes life possible on earth.
2. Releases its energy in two ways, namely:
   - The usual normal flow of light that makes life possible on earth(life supporting energy)
   - And the more violent and dramatic ways that gives rise to burst of light, particles and magnetic fields that can have ripple effects all the way out to the solar system magnetic edge.
3. Helps plant to make (manufacture) oxygen for man and other animals use and provides food for plants and all living things through the photosynthetic processes.
4. Has its spectrum close to that of a black body with a temperature of about 5,800k.
5. Provides enough energy to power nearly all atmospheric process and manifest itself various atmospheric physics system
6. Provide the driving force and weather.

3.3 THE RACE WITHIN THE EARTH'S ATMOSPHERE:
SUN-EARTH ATMOSPHERIC PROCESSES

The transfer of energy from the sun across nearly empty space (vacuum) is accomplished primarily by radiation (transfer of energy by electromagnetic wave motion.

When the suns radiation (energy and light) destined to the earth's surface enters and travels through some distance into the earths atmosphere, the particles of gases in the atmosphere interacts with the electromagnetic radiation by the following mechanisms and processes, depending on the size of the particle, the wavelength of the radiation and the atmospheric level (height) of the atmosphere.

1. **Scattering:** scattering of radiation occurs when particles of large gas molecules present in the atmosphere interacts with and because the electromagnetic radiation travels through the atmosphere. There are three types of scattering which takes place in the atmosphere are:

- Raleigh scattering: This occurs when particles are very small compared to the wavelength of the radiation. The particle that causes scattering in the atmosphere include small speck of dust, nitrogen and oxygen molecules. Raleigh scattering causes shorter wavelength of energy to be scattered much more than longer wavelength. Raleigh scattering is the dominant mechanism in the upper atmosphere, and the phenomenon is the reason the sky appears "blue" during the day. This is because as sunlight passes through the atmosphere, the shorter wavelength (i.e. blue of the visible spectrum are scattered more than the other longer visible wavelength). On the other hand, at sunrise the atmosphere is nearly transparent to visible radiation between 0.34 and 0.70 micrometer (atmospheric window) thus leaving the longer portion of the longer wavelength to penetrate the atmosphere. This preferential scattering of wavelength is why the sky appears reddish early in the morning and late in the evening, but bush in the midday when the sun is directly overhead.

-Mie scattering: This occurs when particles are just about the same size as wavelength of the radiation. Common vapor which tends to affect longer wavelength than those affected by Raleigh scattering. Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud position are overcast.

-Nonselective scattering: this occurs when the particles are much larger than the wavelength of radiation. The particles that are responsible for this type of scattering are water molecules in clouds and atmospheric pollutants. This type of scattering causes fog and clouds to appear white to our eyes because blue, green and red light are scattered in approximately equal quantities (blue+ green+ red light = white light). The scattering processes works as follows; a particle momentarily traps some part of the solar spectrum that strikes it and then releases that same energy in all directions. Consequently, one half of the radiation that is scattered is returned to space and the other half is sent down to the earth surface. Since the wavelength scattered depends on the size of the scattering particles, haze and smog particles which are relatively larger particles scatter all the wavelengths, while air particles which are smaller scatter the smaller wavelength. Thus the presence of smog and have (small water droplets) particles, gives the sky a milky appearance.

Absorption: Absorption is the process by which energy that is transferred to any matter is retained by the substance and converted into heat energy due to the fact that the absorbed radiation causes the atoms in the substance move faster and become warm. The creation of heat energy causes the substance to emit its radiation. This is one of the main mechanism at work when electromagnetic radiation interact with the atmosphere. The absorption of solar radiation by a substance in the earth occurs at various wavelengths. The substances in atmosphere (atmospheric constituents) that are responsible for absorption are ozone, carbon dioxide (and the greenhouse gases), and water vapor. These absorb are as follows

-Ozone: Ozone absorbs the harmful ultraviolent radiation from the sun that is capable of harming all living things on the earth especially human skins, eyes, and other organs of the human body. Infact this protective ozone layer in the atmosphere, which acts as a filter radiation, our skin will burn and our eyes will be sore when exposed to sunlight. This can still happen when the ozone layer is or damaged by atmospheric pollutants such as carbon dioxide and other greenhouse gases.

Carbon dioxide and the greenhouse gases: These tends to absorb radiation strongly in the far infrared portion of the spectrum;(which is associated with thermal heating) serves as a trap to this heat inside the atmosphere, causing the atmosphere to heat up and the heat trapped within the atmosphere.

Water vapour: Water vapour in the atmosphere absorbs the much of the incoming longwave infrared radiation and shortwave microwave radiation (between 22um and 1m). The presence of water vapour (i.e. high humidity). This is the idea of "perceptible water" in the atmosphere which determines rainfall pattern and rate as well.

In general, the absorption of solar radiation by these substances in the earth's atmosphere results in the temperature that is high enough such that these bodies would emit their own radiation in the longwave band. Further, this emission of radiation is in all direction so a sizable proportion of this energy is lot to space.

If the matter that absorbs the radiation is a gas, the radiation can affect it in the following ways depending on the size and complexity of the gas molecules, and the wavelength of the radiation that is involved.

-The shortest wavelength of solar spectrum (ultraviolet <0.12 microns) are absorbed by oxygen and nitrogen in the upper atmosphere above 100 kilometers (ionosphere).

-UV radiation between 0.12 and 0.18 microns are absorbed by oxygen above 50 kilometers.

-UV radiation between 0.18 and 0.34 microns are absorbed between 50 kilometers and 10 kilometers by ozone or ionized oxygen (three molecules of oxygen bonded together).

The atmosphere is nearly transparent to visible radiation between 0.34 and 0.70 micrometers (atmospheric window).
-The infrared part of the solar spectrum is partially absorbed by water vapour in the atmosphere below 10 kilometers.

If the energy of the radiation is strong enough the atmospheric gaseous and particulate molecules can be broken apart. Each mode of these energy absorptions occurs at a specific narrow band.

SUMMARY OF THE ABSORBTION OF SOLAR RADIATION IN THE ATMOSPHERE IS AS GIVEN IN THE TABLE BELOW:

Wavelength of Radiation	Material Absorption	Atmospheric Level of Absorption
< 0.18 um	Molecular oxygen	Upper atmosphere (3100km)
B/W 0.18 and 2.0um	High Density Oxygen	Lower atmospher
B/W 2.0um and 2.9 um	Molecular Oxygen and Ozone layer	Stratosphere (15-10km)
> 0.29 um	Water vapour and dust (weak absorption of about 20%)	Lower Troposhere

The following differences exist between Absorption and scattering in the atmosphere:

1. Whereas scattering takes place at all wavelength, absorption is a selective process.
2. The molecules in the atmosphere that are responsible for absorption of solar radiation are H_20 (water vapour),Co_2, No_2 ,O_2,O_3, No, and CH_4 and Co - mainly gas molecules, whereas those responsible for scattering are air molecules, clouds, ice particles, etc.
3. The visible region is relatively free from absorption bonds, whereas substantial absorption occurs in the UV (O_2,N_2,O_3, and O) and in the IRCH $_20$,CO_2 CH_4 and (O). Thus the region constitute what is known as the" atmospheric window".

REFLECTION: Reflection is the final process in the atmosphere that modifies meaning solar Radiation in the earth atmosphere. Reflection is a process where sunlight falling on a surface is redirected by 180^{o} after it strikes an atmosphere particle. This reflection causes 100%loss in insolation. The earth's reflection occurs on some fields, oceans, sea, river, surface, snow, and on clouds.

The fraction of solar radiation incident on the earth that is called the" Abeldo" (A). Values of measured albedo is about 30% of the incoming solar radiation. This means that 30% of the incoming solar radiation on the earth's surface is reflected while the remaining 70% is absorbed. Clouds are the major contributor to the albedo, reflecting about 25% while the earth's surface reflect only 5%. The reflectivity of clouds occurs when light is intercepted by particles and frozen water in clouds. Different materials in the atmosphere and the earth's surface and their reflectivity is as given in the table below;
Different materials in the atmosphere and the Earth's surface and their reflectivity is as given in table below

Object		**Reflectivity (Percent %)**
Cloud	Thick Cirrus	20
	Alto stratus	50
	Alto Cumulus	50
	Cumulus	70
Open water		3-8
Open water polar region		25 (due to glancing angle of incident radiation)
Snow and Ice		30-70 (Clean fresh snow at high ends
Arable land coniferous forest		10-15
Deciduous forest		18
Desert		30

Since the earth and its cloud reflect up to about 30% of radiation, it means that the earth is not a blackbody.

SUMMARY OF THE EARTH ATMOSPHERE ON INCOMING SOLAR RADIATION

Scattering: 7% of incoming solar radiation is scattered back to space.

Absorbing: 17% of incoming radiation is absorbed at various at various levels in the atmosphere

Reflection: 35% of incoming solar radiation is reflected back, to space. Out of this, 24% is reflected by clouds, 4% by the earth's surface, while the remaining part is reflected by clouds and atmosphere ice crystals. Infact the reflectively of clouds car range from 40% to 90%.

SOLAR INFLOW TO THE EARTH SURFACE:

The radiation inflow from the sun to the top (tip) of the earth atmosphere is constant and therefore referred to as solar constant with a value of 13.67w/m ^{2} and an average density of 170w/m^2 and is viewed as: The flux of solar energy at the tip (top) of the earth's atmosphere and defined as the amount of solar energy per unit time passing through unit area at right angles to the direction of the solar beam measured just outside the earth's atmosphere.

Due to the various atmospheric events (such as absorption, scattering, sunlight, which is solar radiation passes through to the atmosphere; that are discussed above solar radiation at the earth's surface is greatly reduced to about 1,000 w/m for a surface perpendicular to the sun's rays at sea level on a clear day. Radiation received on the earth surface also varies widely due to local variation in the atmosphere such as water vapor, clouds, pollutants, (aerosol movement), latitude of the location and the season of the year and time of day. These changes include variation in the overall power received, the spectral content of the light and the angle from which light is incited on a surface.

For example, Desert region tend to have lower variation due to local atmospheric phenomena such as clouds. Equatorial regions have low variability between seasons. Some places on the earth receive more than 4,000 hours of sunlight per year (more than 90% of the maximum possible) as in Sahara. Others receive less than 2 hours, as in regions of frequent storminess, such as Scotland and Iceland. Over much of middle-latitude region of the world, the amount of sunlight varies, regularly as the day progress, owing to the greater cloud cover in the early morning and during late afternoon.

In general the amount of energy reaching the earth every hour is greater than the amount of energy used by an earth population over an entire year. It is infact said that in an hour about 430 quantities joules of energy from the sun hits the earth.

4.1 DIRECT AND DIFFUSE RADIATION

Solar inflows from the sun comes into the earth surface either as direct or diffuse radiation. Despite the absorption, scattering (reflection) of solar radiation passing through the earth's atmosphere , some of the incoming ultraviolent, visible and limited portion of infrared (thermal) energy (together sometimes called shortwave radiation) from the sun manages to arrive the surface of the earth angles as direct radiation. Direct radiation is therefore radiation that is incident directly) (at right angles-90%) on the earth's surface without being scattered. On the other hand, diffuse radiation caused by various atmospheric processes or phenomena. Both Direct and Diffuse radiation have the following special features:

4.2 SOLAR SPECTRUM:

The energy that leaves the sun's surface and travels towards the earth is not in discrete form but travels in the form of electromagnetic spectrum (the solar spectrum) that is continuous extending from wavelength less than (10^{-15}m) to many hundreds of meters. This energy or radiation continuum is called solar spectrum and it ranges from very high energy (frequency) of x-ray type to low energy (or frequency) of x-ray type to low energy (or frequency) of radio waves. 98% of the total energy emitted by the sun is effectively carried by wavelength between 250 and 3,000nm. The three main regions of the solar spectrum are

Ultraviolet (UV) light region which has short wavelength that is between 0.100nm (10nm) and 0.40nm (400nm). Although ultraviolet light constitutes only a very small portion of the total radiation, this wavelength region carries over 80% of the energy of the entire solar spectrum. Hence it is capable of causing skin diseases and eyesore. Optically UV light are invisible to human eyes. UV radiation is classified into UVA, UVB, and UVC, with wavelength regions UVA (-3-15-400mm), (280-400nm) and (100-280nm), respectively

Visible light region: This region has wave length between 0.4nm (400nm) and 0.8nm (800nm) and constitutes nearly half of the total radiation received at the surface of the earth. Visible portion of the solar spectrum is that part that is visible to the human eye. The spectrum is continuous with no clear boundaries between one colour and the next.

The primary properties of visible light are: intensity, propagation, direction, frequency and wavelength of spectrum and polarization. Its speed in vacuum is 299, 792, and 458 meters per second (usually approximated to $3x10^{8}m(s^{-1})$, is one of the fundamental constant of nature. Visible light is located between infrared (IR) and ultraviolet (UV) radiations.

The colour component of visible light include: violet, blue, green, and yellow, orange, red. The spectral colors and their properties are shown in the table:

Colors	Wavelength	Frequency (hz)	Photon energy (eV)
Violet	380-450	680-790	2.95-3.10
Blue	450-485	620-680	2.64-2.75
Cyan/indigo	485-500	600-620	2.48-2.52
Green	500-565	530-600	2.25-2.34
Yellow	565-590	510-530	2.10-2.17
Orange	590-625	480-510	2.00-2.10
Red	625-470	405-480	1.65-2.00.

Infrared radiation: Solar infrared radiation have longer wavelength than visible light and can pass through dense region of gas and dust in space with less scattering and absorption. Thus infrared can also reveal objects in the universe that cannot be seen in visible light using optical telescopes. IR radiation is about 52-55% (above700nm) of solar spectrum at earth surface above.

4.3 FEATURES OF ELECTROMAGMETIC RADIATION:

The electromagnetic radiation exist both as a wave and as particles with both electric and magnetic components. EM radiation has the following features as a wave:

Crest- highest point in the wave

Trough-lowest point in the wave

Wavelength- horizontal distance between successive crests trough and other part of the wave

Wave height- vertical distance between crest and trough

Amplitude- amount of displacement from the equilibrium or rest position, equal to one half of the wave height
Period: time it takes for successive crest or through to pass a specific point
Frequency: the inverse of a period. The number of crest that pass a point during a set of time interval

4.4 SOLAR POWER Nuclear fusion reaction taking place in the interior (core zone) of the sun produces about 380 billion megawatt per second of power. This is possible because each second about $7x10^8$ tons of hydrogen to about $9.5x10^7$ tons of helium and $5x10^6$ tons(about 3.68e 33 ergs) of energy in the form of gamma rays. On the earth surface, solar power is the amount solar energy from the sun to the earth atmosphere per unit time. It is the rate at which energy is transferred. Another measure for solar control or flow is solar flux which is defined as energy flow per unit area (i.e the amount of solar energy per unit time per unit area)

SOLAR TEMPERATURE: If we treat the sun as a heat radiator which emits radiant energy (heat) by virtue of its temperature into outer (cooler) space. It can be therefore be compared to a "blackbody" which is capable of emitting and absorbing all radiations on it. The emission of radiation will depend on its temperature and on other physical parameters. The spectral curves of s sun when compared to that of a blackbody, temperature distribution at various temperature approximate well to that of a blackbody at 5,800k. Thus the sun can still be tested as a black body with temperature near 5,800k. This curves is shown below:

5.0 SOLAR ENERGY MANIFESTATION IN THE EARTH ENVIRONMENT

Solar radiation that impinges on the earth surface is manifested in various heating processes that eventually generates a number of atmospheric system that lead to weather system and climate regimes of the world

5.1 SOLAR HEATING OF THE EARTH SURFACE

Direct and Diffuse heating: The most obvious form of solar manifestation on the earth is the direct and diffuse heating of surfaces including land mass, open water bodies,(oceans, seas etc.), Green vegetation(trees, grasses, etc.) and solar energy converting devices. Such heating processes can be utilized by nature to yield atmospheric systems and by man to operate solar energy conversion devices. Since direct radiation can be focused while diffusion radiation cannot, the technologies for harnessing them and their efficiencies will also differ from each other.

EARTH INSOLATION OR IRRADIANCE:

About 42% of incoming radiation is affected by atmospheric particulate matter into space while about 58% of the energy from the sun in the form of short electromagnetic radiation (UV and visible regions of the spectrum) reaches the surface of the earth as solar insolation or irradiance (intercepted or received solar radiation on the earth surface per unit area per unit time). Some of this radiation is reflected by shiny surface such as snow or ice on the earth surface while the remaining is absorbed by the earth other surface. Once absorbed by the earth surface, the shortwave electromagnetic radiation is converted to longwave thermal radiation within just a few meters below the earth surface, and is re-radiated outwards from the earth surface as earth's radiation (thermal radiation).

Earth insolation and irradiance directly affects the temperature of earth and places important role in regulating the temperature of the earth crust, surface water and the lower atmosphere. Every surface on the earth absorbs and reflect energy at varying degrees based on its color and texture. Dark colored objects absorb more visible radiation while light colored surfaces reflect more visible radiation. On the other hand shiny or smooth objects reflects more, while dull or rough surface absorb more.

Differences in reflection impact temperature, weather and climate:

Earth surface temperature: Since the energy flowing to the surface of the earth is that coming from the sun(electromagnetic radiation) and the energy going away from the earth surface is in the form of infrared(heat) radiation given off by the earth surface by the warm body, these energies can be determined on the earth surface using the Stephan's law ,and the earth surface temperature can easily be calculated by simply equating the energy absorbed by the earth (insolation) to that re-radiated(thermal radiation) by the earth, we neglect the fact that we live at different latitude and the fact that different surfaces reflect differently and that our geographical location differ and the seasons also differ.

Energy absorbed = s (solar constant) x A (cross-sectional area) xαxt

$\rightarrow E = S\pi R^2{}_{\epsilon}\ \alpha t$--------(1)

Energy by the earth =$\sigma\epsilon\ T^4$ x surface area x time

$\rightarrow\ E = \sigma\ \epsilon T_E{}^4\ 4\pi R^2 t$----- (2)

Equating the energy Absorbed to the earth reradiated gives

$S\pi R^2{}_E\ \alpha t = 4\pi R^2{}_E\ \sigma\ \epsilon\ T_E{}^4\ t$-----(3)

Where s= solar radiation, R_E= radius of the earth

α= absorptivity of the earth surface(i.e. Fraction of the incident solar radiation absorbed by the earth

σ = emissivity of the earth surface (fraction of the earth absorbed radiation that will be emitted, and for the earth, E =1)

Stephan's Boltzmann's constant =0

TE = temperature of the earth

Making TE the subject of the equation gives

$Te^4 = (S/T4)(\alpha/E) =$ o.136 watts cm-2

=278k or 5^oC.

This temperature result is not representative for the entire earth surface. We can obtain correct result by considering all the factors neglected initially as follows

(i) Latitude considerations will lead to the equation

$2RW\cos^2\theta S = 2\pi RW \cos\theta\, \sigma\, T(\theta)^4$-------(5)

Solving for $T(\theta)^4$ gives

$T(\theta)^4 = S/R(\cos\theta/\pi)$--------(6)

$\rightarrow T(\theta) = 296(\cos\theta)^4\ ^OC$-------(7)

Using appropriate value of gives the table below

θdep	k	^OC
0(equator)	296	23
30	286	13
60	241	-32
85	764	-109
90(poles)	0	-273

Although these results are close to but they are not he exact temperature at those latitudes. To obtain the correct temperature there is the need to consider all the factors or boundary conditions that affect temperature on the earth surface. These factors are

(i) Reflectivity (Albedo) of the surface

(ii)Temperature distribution along the latitudes

(iii) Location on the globe due to earth's inclination
(iv) Time of the year
(v) Seasonal and geographical effects.

Energy Budgets: when solar radiation flows into and impinges on the earth atmosphere and surface, almost all the energy the neighborhood of the earth will eventually leave the earth. This means that energy is conserved on the earth's surface over a short term duration. Nevertheless, the energy balance over one year presents a good average of the balance of energy on the earth's surface. By the demand of energy balance on the surface of the earth over a long period of time, the energy flowing to the earth must equal that flowing away from it neglecting the local differences occurring over the earth atmosphere land and ocean.

If there is a conservative of energy on the surface of the earth surface, then energy will not accumulate or deplete on the earth surface. This balancing of conditioning of energy on the earth surface over a long period of time is what is termed or called energy budget.

5.2 ATMOSPHERIC SYSTEMS

A. ATMOSPHERIC CIRCULATION AND WIND SYSTEM

About, 47% of the solar radiation that comes into the earth's surface is absorbed by the earth surface (soil and water body) and converted into sensible heat to warm up things in the environment. The sensible heat is also transferred to the lower atmosphere by conduction or transported horizontally and vertically by convection. A temperature difference is created by radiative and convective effects in the atmosphere. This process of heating of the lower air causes it to rise while in the air column just above it subsides to the lower level and becomes heated and rises while another air column subsides to take its place. This repeated rising and falling of different air columns is what creates winds on the local scale and wind system (such as the North east trade wind, the South west trade wind and the monsoon wind systems) on the larger country and continental scales. In addition the wind systems themselves contribute in generating waves in large water bodies as well as we can see in the next segment.

B. OCEAN CURRENT AND WAVES

The wind generated by the suns heating generates ocean currents as the wind energy sweeps over the ocean and sea surfaces while the solar heating of the water surfaces creates differential heating of the water surfaces leading to ocean waves. The movement of oceans/sea current and waves is associated with large amount of kinetic energy.

It is estimated by 2 to 3 million megawatts could be generated from the power of waves that strike the shorelines across the world. However, there are only unlimited sites where this energy can be harnessed. The areas with an average density of 40MW per kilometer of coastline are considered economically viable for generating electricity from the ocean waves.

C. OCEAN THERMAL ENERGY

This type of energy manifestation arises because of difference in temperature of sea surface heated by the sun and colder waters found at ocean depths. To harness this form of energy, devices known as ocean thermal energy conversion power plants (OTEC Power plants) are used. To use this plant a difference of 20^0C or more between the temperature of the surface waters and water at depths of 1,000 meters is required. Both winds, waves and ocean thermal energy are potential sources of useful power namely: wind energy, ocean wave energy and ocean thermal energy as well as hydro power, all of which are exploited to generate electric power.

D. CONVECTION, EVAPORATION AND PRECIPITATION (RAINFALL) PROCESSES

Convection: substantial amount of latent heat and sensible heat transferred horizontally on the earth surface is by convection. Major wind flows on the earth are driven by temperature between the equator and the poles. The wind in turn drives the ocean currents. These flows are usually aided by three factors namely:

The Coriolis force, land mass and seasonal changes.
The Coriolis force is an inertial or fictitious force that acts on objects that in motion within a frame of reference that rotates in respect to an inertial frame. In a reference with clockwise rotation, the force acts to the left of the motion of the object.
The net effects of both wind and ocean current is to carry very comparable amounts of energy from the equator to Polar Regions. This reduces the temperature difference between the temperature and the poles below that calculated for radiated effects alone. Thus the temperature difference created by radiative effects are further reduced by convective effects through

Evaporation: This process of creation and reduction of temperature differentials create the wind systems on land and currents on water bodies. It also gives rise to transport of water from ocean to land, weather and climate regimes rainfall, etc. and in effects the hydrological cycle.

E. EVAPORATION AND PRECIPITATION: Evaporation is a major user that comes from the sun into the earth surface. When solar radiation is incident on the earth surface about 23% of the radiation is used to heat up and evaporate water from open water surfaces(oceans, seas rivers, creeks, lakes, ponds and swimming pools) and from the soil and leaves of trees and grasses (also called evapotranspiration). During the evaporation and evapotranspiration process the sensible heat from the sun is converted to latent heat which is carried along with and within the water vapour. As the water vapour moves upward with the wind, the latent heat is transported with it until at greater height when the water is cooled by the adiabatic cooling process, the heat is converted back again to sensible heat, while the water vapour condenses back to liquid water droplets which fall back to the earth as rain. The conversion of latent heat to sensible heat during the precipitation process is the reason why we feel excessive heat just before rainfall. Rainfall in turn increases the water reserves in rivers and in other water bodies which is then used as the source of hydroelectric power.

F. PHOTOSYNTHESIS PROCESS AND FOSSIL FUELS

(i) Photosynthesis: Green plants are also able to utilize solar energy (sunlight) to convert atmospheric carbon dioxide and water into carbohydrate and other major organic molecules and oxygen through the process called photosynthesis. These carbohydrate and organic materials form food for animals (including man) and a wide variety of plant materials, many of which are used as fuel (eg wood, biomass, biofuel, and biogas). The simplest form of photosynthesis reaction may be viewed as

$$H_2O + CO_2 + \text{Light} = \rightarrow \quad CH_2O \quad + \quad O_2$$

Water + carbon dioxide (solar energy) carbohydrate + oxygen

Here carbon dioxide is fixed and converted from the inorganic to the organic state (carbohydrate)

(ii) Fossil fuels: Photosynthesis that had occurred in the past, produce plants and planktons that have been buried deep inside the earth a long time ago is also the original source of fossils fuel such as coal, oil, peat and natural gas.

The use of solar energy to produce these fuel sources through the process of photosynthesis help to reduce the solar power on the surface of the earth and make solar energy the ultimate energy resource for life and activities on earth.

6.0 SOLAR RADIATION INTERACTION: Nothing is hid from the heat there of the lower atmosphere surrounding the earth surface including everything in it (air, gas molecules, clouds, land mass, water bodies, plants, animals, solar energy appliances and devices, etc. Indeed nothing is heed from the heat thereof.

6.1 INTERACTION OF EMR WITH THE EARTH SURFACE

Electromagnetic radiation that passes through the earth's atmosphere without begin absorbed or scattered (direct solar radiation) reaches the earth's surface to interact in different ways with different materials constituting to the earth surface. There are three main ways in which the direct total incident radiation reacts with the earth surface materials. These are; Absorption, Transmission, and Reflection and take place as follows:

Absorption (A) occurs when radiation (energy) is absorbed into the target, causing them to start vibrating and move faster. This increases their temperature and leads to warming up of the target. Energy that is not absorbed by the body is either transmitted or reflected. Absorption occurs mainly on opaque materials and surfaces such as soil, dark objects, and targets, etc.

Transmission occurs when energy passes through the body without being absorbed or reflected. Energy that is transmitted do not affect the target in anyway at all because it simply goes through without interacting with the atoms of the target. Transmission occurs in transparent surface such as water, transparent materials such as water glasses, celephone, accrylac glasses, celophene, e.t.c.

Reflection (r) occurs when radiation bounces off the target and is redirected. Reflection from surfaces (targets) occur in two ways as follows:
Specular reflection: specular reflection occurs when the surface is smooth and mirror-like or smooth reflection occurs, here all (or almost all) of the incident is reflected in one direction. This type gives rise to images.

DIFFUSE REFLECTION: This type of reflection occurs when the surface is rough and the energy is reflected uniformly in almost all directions and does not give rise to images. Most surface features on the earth's surface lie somewhere between perfectly specular and perfectly diffuse and somewhere in-between depending on the surface roughness of the feature in comparison to the wavelength of the incoming radiation.

If wavelength are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example fine grained sand would appear fairly smooth to long wavelength microwaves but would appear rough to visible wavelength. Infact how much of the energy is absorbed, transmitted, or reflected by a material will depend on; the wavelength of the energy, the material constituting the surface, and the condition of the feature.

6.2 INTERACTION OF ENERGY WITH SAMPLE TARGETS ON THE EARTH SURFACE

Energy within the visible and infrared wavelength will interact with various targets on the earth's surface in the following ways;
Vegetation: A chemical compound in leaves of plants called

chlorophyll strongly absorbs radiation in the red and blue wavelength but reflects green wavelength. This is why leaves appear green to our eyes. Leaves infact appears "greenest" in summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll so there is less absorption and proportionately more reflection of the red wavelength, making the leaves appear red or yellow is a combination of red and green wavelengths.

The internal structure of healthy leaves act as an excellent diffuse reflectors of near infrared wavelength. If our eyes were sensitive to near infrared, trees would appear extremely bright to the eyes at these wavelength. Infact the reflectance of near IR in plants is a way of determining how healthy (or unhealthy) a vegetation is.

Trade wind, which prevails around just north south of the equatorial belt. The tropical Easterlies and prevailing west lies, which are prevalent in the middle latitude and temperature regions called monsoon winds and polar westerlies(which prevails around the poles). This wind belts are associated with those three wind cells (Hadley cell-nearest to the equator Ferrell cell in the mid latitude and the polar cell.

These belts contains five wind zones namely; polar easterlies, Polar westerlies, prevailing monsoon, winds in the southern hemisphere, monsoon prevailing winds in the the northern hemisphere, the north east and the south west trade wind. There is a sixth wind zone between the westerlies and the trade winds both north and south called the horse latitude, making the wind zone up to eight(8).

The direction of wind flow associated with wind belt zones flows from direction located within its name for instance the northeast trade winds flows from the northeast to the southwest and vice versa for the southwest trade winds. Due to the rotation of the earth, winds does not flow simply across the equator like from north to south or vice versa, rather are deflected to the right in the northern and to the left in the southern hemisphere. This effect is known as coriolis effect or force and adds greatly to the atmospheric airflow mixture and weather variability. As a result of the movement of atmospheric materials, transported and driven by wind and energy from the sun respectively, climates are created and weather occurs.

Without wind, weather would not exist. Wind is the vehicle by which water vapour are moved from one area of the globe to another, and with its interdependent relationship with other cycles of the earth, like ocean currents, is the vehicke by which water vapour, and by consequence temperature variation are moved from one area of the globe to another, creating variation with specific climate zones.

Temperature Modification due to Clouds and Convective activities. A cloud is a visible mass of condensed water vapour

Temperature Variation Due to cloud cover, Humidity and convective systems

A cloud is a visible mass of condensed water vapour floating in the atmosphere, typically high above the general level of the ground. Meteorologically, cloud is an aerosol consisting of a visible mass of minute liquid droplets, frozen crystals, or other particles suspended in the atmosphere of planetary body or similar space. Water or various other chemicals may compose the droplets and crystals. On earth, clouds are formed as a result of saturation of air when it gains sufficient moisture(usually in the form of water vapour) from an adjacent source to raise the dew point to the ambient temperature stratosphere and mesosphere). There are four main types of clouds, namely

- Circus Clouds: This wispy clouds seen high in the sky
- Cummulus Clouds: Puff clouds that are usually scattered through the sky and are formed when warm air rises, carrying water vapour with it by evaporation. They look grey white which carries no rain or dark gray which carries rain with it.
- Stratis Clouds: A huge thick blanket covering the sky and they surely bring rain if it is warm and snow if it is cold. When they are formed near the ground, they form tog.
- Nimbus Cloud. A ready to rain or snow cloud. They are dark and are common during thunder storm along with thunder activities and lightening (convective activities).They can be a combination of two clouds, like cumulonimbus=cumulus+nimbus or Stratonimbus=stratus+nimbus.
- Convective clouds: Clouds that are form by convection as warm air rises because it is less dense than the surrounding atmosphere. Camillus clouds, cumulonimbus clouds etc are examples of cumulus clouds and they usually lead to deep convective activities like thunderstorm and line-sqaul or sqaul line (chain of thunderstorms).
- The term convective activities is a general term for manifestations of convection in the atmosphere, alluding particularly to the development of convective clouds and resulting weather phenomena, such as showers, thunderstorms, squals, hail, tornadoes, etc.

- Orographic clouds: These are clouds that develop in response to the forced lifting of air by a change in atmospheric conditions caused by a change in elevation, primarily due to mountains.

  Omotosho and Okujagu (1995) studied the interactive roles of some dynamical and thermodynamical properties of the basic flow within and above the boundary in the initiation and organization of deep convective systems over West Africa. The results shows that deep convection is suppressed or layer is shallower than one kilometer, the mid-tropospheric wind maximum (i.e the African easterly Jel-AEJ) at about 700hpa is ill-defined and the boundary layer vertical wind shear (both u and v components) is negative. On the other hand, wide spread thunderstorms should be expected whenever there is simultaneous presence of a moist layer of at least one kilometer deep, positive boundary layer wind shears and a distinct AEJ. Disturbance and squall lines almost always form and propagate through the basic flow if, in addition to the wide spread convection requirements, the core of AEJ is positioned over and above the zones of strongest near-surface wind shear.

Okujagu and Omotosho further investigated the roles of some mean flow parameters and dynamic processes necessary for the formation of widespread deep convective activities over Nigeria. These parameters include the low-level and 700mb winds known as African Easterly Jet (AEJ), spatial distribution of vertical and variability of the zonal and meridional winds, the spatial and temporal heights of the moist layer and the anomalies of equivalent potential temperature and the specific humidity.

It was found that wide spread thunderstorms and /or organized line squalls around the left entrances and right exits in contrast with the middle latitude situation where weather development is normally expected around the right entrances and left exits of the jet streams. Also, positive(westerly) low-levels(boundary –layer) zonal and meridional wind shears were found to be more important to storm initiation due to their overturning effects. On the other hand, negative (easterly) low-level shears led to suppression of convective activities. Also, the depth and strength of convective activities were found to be affected by a deepening of the moist layer (represented by the height of the positive (V) components of the wind) in the preceding twenty four horns. A reasonably deep layer of moisture of at least 1.5km favors wide spread deep convection. Mapping of the positive vertical wind shears, height of moisture greater than – 0.km were found to have very high correlation with areas of line squall/thunderstorm occurrences while anomalies of the equivalent potential temperature and specific humidity gave minimal correlation with convection.

6.3.2 Interaction of Temperature With Parameters Of Evaporation, Humidity And Precipitation Factors.

Having looked at temperature modification by various weather systems, we now look at the interactions of temperature itself on the components of weather namely; Evaporation and Evapotranspiration, Humidity and Relative Humidity, Precipitation and Precipitable Water (Parameters of weather and Climate). The extent to which temperature and by extension sunlight and solar radiation impact on Evaporation, Humidity and Precipitaion is an important factor which indicates the concentration of water contents in water vapour (gaseous state of water) that is present in the air, the amount of water needed to achieve saturation during evaporation and the likehood for precipitation, dew or fog that can precipitate out of the vapour when condensed.

-INTERACTION/IMPACT OF TEMPERATURE ON EVAPORATION AND EVAPOTRANSPIRATION

It is found that as temperature increases, the rate of evaporation increases as well due to increasing kinetic energy of the surface molecules which helps them to be free and become vapour. Hence, at higher temperature, higher rate of evaporation takes place and the water va[pour gathers above the water surface from where the wind blowsm them away and around or even lift them to higher levels. The more water evaporates in a given area, the more water vapour rises into the air, and the higher the humidity of the area. Hot places tends to be more hum9id than cool places because heat causes water tom evaporate faster.

Temperature, Humidity and wind speed all affect the rate of evaporation. Generally, the rate of evaporation increases when temperature increases while humidity and wind speed remains constant because warmer air can hold more watern than colder air. But an intermolecular force increases with temperature the rate of evaporation then decreases due to the fact that higher intermolecular forces make it less likely for the molecules on the surface to escape fromthe liquid and become vapour(gas). Thena point of equilibrium is reached when rate of evaporation equals rate of condensation.

Evaporation from vegetation cools the local environment but if there is no moisture to be evaporated, heat will intensify and be prolonged when there is no kmoisture supply to the environment. Also, rate of evaporation not only increases with intermolecular face and temperature but also with surface area of matter.

When evaporation is taking place on land and otherm surface, and transpiration is taking place from plants, then their combined effect is referred to as **Evapotranspiration(ET)** and belongs to the field of ET is therefore the sum of Evaporation and Transpiration. Adequate organization and well planned ET management will include proper water resources management and irrigation design and schedulling which will in turn boost agricultural crop productivity and supply and security.

Edebeatu and Okujagu (2014, 2015, and 2016) estimated the Reference Evapotranspiration in the Semi-Arid Region of Nigeria. Also, the callibration Scarce region using the Hagreaves Equation was carriekd out. Finally, a New Correlation Model for estimating Reference Evapotraspiration in a Semi-Arid Region was developed. The developed Model which was used to estimate from 22 locations showed significant agreements with the established standard of Penman-Monteith and can be used to estimate evapotranspiration in any dat-sparse region of the world especially in Nigeria to assist in boosting agriculture and National Food Security . The Emperical model recorded best ETO performance evaluation in the season valuation corresponding to cereal cropping season.

-INTERACTION AND IMPACT OF TEMPERATURE WITH HUMIDITY AND RELATIVE HUMIDITY

When temperature increases, humidity decreases, while if temperature decreses, humidity increases provided the water content of the atmosphere remains the same. This is because, as temperature increases, air can hold more water molecules and its relative humidity will decrease and cold air does not require as much moisture to become saturated like warrmer air. When temperature drops, realtive humidity increases. High relative humidity of the air occurs when air temperateure approaches the dew point value. Temperature therefore approaches humidity which in tuern affects the potential for precipitation. Therefore, the understanding of the interaction between temperature and enumerous phenomena of weather and climate is very important. Hence, temperature and humidity affects earth's weather, human health and well being.

Relative humidity represents a percentage of water vapour in air that changes when air tmeperature changes. HUmidity makes air muggy and uncomfortable and also causes our bodies to overheat , ghet exhausted easily and pose a potential change to our health and general well being.

Okujagu and Igbudu(2009) studied the effect of Ambient temperature and Relative humidity on the performance of some photovoltaic power systems in parts of Rivers State and Bayelsa State. The study concluded that Ambient temperature found to dominant roles in the power output and conversion efficiency values of the systems for many of the installations than relative humidity. Therefore, Ambient temperature seemed to be the driving force from the power output and conversion efficiency values for the photovoltaic systems irrespective of the seasons while relative humidity seemed to play dominant role at one time and complient any role at other time, depending on the seasons and locations in Rivers and Bayelsa States.

-INTERACTION AND IMPACT OF TEMPERATURE ON PRECIPITATION AND PRECIPITABLE WATER.

Precipitation is any kind of weather condition where something is falling from the sky. The main forms of precipitation includes drizzle, rain, sleet, snow, graupel and hail. Precipitation occurs when a portion of the atmosphere becomes saturated with water vapour due to evaporation, so the water condenses and precipitates. Two processes namely; Cooling of the air and addition of water vapour to the air or a combination of the two can lead to air becoming saturated. This can lead to smaller droplets coalescing via collison with other raindrops or ice crystals within a cloud and when the droplets are being enough, such that they can't be carried about by the cloud, they begin to fall out from under the cloud as precipitation. Following this process, fog and mist cannot be classified as precipitation but as suspension because in these two processes, water vapour does not condense sufficiently to precipitate.

Temperature and precipitation are the two most important factors of the climate of a place. Both the yearky average temperature and the yearly range in temperature are very important. Likewise average precipitation and yearly variation in rainfall are also very important. Temperatures interacts with raindrops or any precipitation from high up in the cloud to their final target on the ground, drastically affecting the temperature of the water droplets from the rain and precipitations. Most of the world's rain begins as snow high up in the clouds overhead - even on hot summer days because the upper portion of the clouds are well below freezing. But these snowflakes and ice crystals found high up in the clouds, warm and melt into liquid water as they exit the parent cloud and enter the warmer air below it.

As the melted raindrops continue to descend, they can become cooler through evaporati9on in the process, due to "Evaporation cooling" where rainfalls into drier air, causing that air's dew point to increase and its temperature to lower. This is why rainfall is associated with cooler air. In general, as precipitation nears the ground, the atmosphere's temperature profile determines the type of precipitation (rain, snow, sleet or freezing rain) that will reach the ground. If this temperature is above freezing, the precipitation will be rain. On the other hand, if the temperature is below freezing, the precipitation will fall as snow, sleet or freezing rain, depending on how much lower than freezing the range of air temperature is.

In general, when condensation takes place and rain is about to fall, the water vapour loses its latent heat of vapourisation, whic is converted back to sensible heat. This is the reason we feel "Excessive heat" just before rain fall.

Again, when it seems that rain is inevitable, if there is increase in air temperature due to surface heating or if more solute is added to the atmosphere to create more condensation nuclei this redistributing water droplet, then rain fall will dissipate and rain will not fall again, then the weather will become bright again.

Precipitable water is the depth of water in a collumn of the atmosphere, if all the water in that collumn were precipited as rain. It is often abbreviated as "TPW" meaning Total Precipitable Water. Precipitable water is a measure of atmospheric moisture and in meteorology it is sometime called "The Height of the moist layer"do, which combines with other meteorological parameters such as the AEJ, potential and equivalent temperatures, wind speed and direction and specific humidity to determine the prevalence or otherwise of convective activities such as thunderstorm or line sqaul. TPW can be estimated using several parameters including; Temperature, dew point temperature, equivalent amnd potential temperature, Relative and specific humidity etc. TPWV can be affected by topography, temperature profile, temperature inversion and other effects.

Udo and Okujagu (2013, 2014, 2015) investigated the use of Welt-bulb Potential and Equivalent Potential Temperatures to the estimation of precipitable water in 28 locations in Nigeria, using mixing ratio, pseudo adiabatic chart are pressure as input parameters. Two new models were developed and used to predict the precipitable water for these stations. The results 73

Obtained from these models were compared to those of thirteen older models. The result also show that the new models performed well in 26 locations while they failed to compare well in only two locations. Longitudinal variations were found to be better for zones (NW, SE, NW and central), while Latitudinal variation were better of only two zones (NC and NW). Also, different condensation levels were observed for different locations. Northern zones have condensation levels lower than 500mb while locations in the North have condensation levels higher than 500mb level. Finally a perceptible water map for each of the twenty eight locations in Nigeria was produced. Also produced was an annual perceptible water is between 16 to 18mm,while the North East have a region around Sokoto with perceptible water of up to about 33mm.Around Jos in the North central and Ogbomosho in the south west , perceptible water was as low as about 13mm.

When compared with the actual rainfall amounts, result shows that for most of the country rainfall correlates very well with the perceptible water. This was not the case with most northern locations where low rainfall does not correlates very well with the high perceptible water obtained in these areas. The reason for this this was adduced to the temperature inversion that exist in that part of the country which suppressed precipitation, tending to low rainfall despite the fact that perceptible water were very high for the region.

6.4 INTERACTION OF RADIATION WITH BIOLOGICAL MATTER ON THE EARTHS SURFACE

6.4.1 Solar energy provides light required for seed germination, leaf expansion, fruiting and thermal conditions necessary for physiological functions of the plant. Solar radiation also plays an important role as regular and controller of growth and development of the plant. In addition, solar radiation also influences assimilation of nutrient and dry matter distribution. All these are possible if the following basic principles for increasing yield are followed.

- Optimum time of sowing
- Optimum plant population
- Timely application of fertilizers
- Irrigation management
-

These principles also help to increase the interception of solar radiation by the foliage so as to get more yields.

When solar radiation falls on vegetation about 10% of the total sunlight is actually absorbed by plants out of which about 3-6% of the overall solar radiation is used by plants for photosynthesis. This means that most solar energy occurs at wave lengths unsuitable for photosynthesis. Hence most of the radiation are reflected by the leaves only the green band is absorbed by plants to power photosynthesis.

Solar radiation falling on plants leaves also cause evaporation to take place through their stomata.

6.4.2 INTERACTION WITH DRY WOODY MATERILAS:

Wood and wood-based material are by nature relatively good heat insulators. The natural fiber of wood is in itself a hollow cell which provides a minute air space, hence an insulating unit. Wood also has a very advantageous blend of R values high strength, light weight, and significant thermal mass hence a lot more thermal storage capacity. Thus it takes longer to heat up or cool down. It can again act as buffer to slow down big swings in temperature of leaving space when used as the outer covering for a building. The effective insulation value is better than just the R value indicate.

Thermal insulation property of dry wood enables it to provide a great solution for the reduction of energy consumption by preventing heat gain or loss through the building envelope. This reduction of unwanted temperature changes decreases the energy demand of heating and cooling systems. Hence by incorporating thermal insulation in the form of wood in elements of the thermal envelope; walls, roofs and flowers, energy generated inside the home can be maintained to improve the thermal comfort of building.

Some local vegetation plants in our environment have been investigated as materials for thermal insulations in buildings by James and Okujagu, Abraham and Okujagu and by Okujagu and a number of undergraduate students. The material have been investigated, are leaves and stems and seeds of Nipa palm, raffia palm leaves and conga grass.

6.5 INTERACTION OF RADIATION WITH SELECTIVE SURFACE COATINGS, THIN FILMS AND NANO COATINGS

When solar radiation interacts with the surface of a solid matter (including selective coating, thin films and Nano coatings or only solid surface), the photons can either be absorbed, reflected or transmitted. Absorption will take place if the body or surface is dark or black to incoming solar radiation. Reflection will occur if the body or surface is shiny or reflective, reflection will take place but if the body or surface is transparent, the radiation will be transmitted through the surface.

The majority of incident photons that is incident on opaque dark bodies is usually absorbed and converted to heat (energy). This heat increases the temperature (thermal energy) of the body or material and causes the surface of the material to emit radiation back to its surroundings at a rate that is dependent on the emissivity and temperature of the body. The rate at which a body radiates or absorbs thermal radiation also depends on the nature of the surface. Objects that are good emitters are also good absorbers. Thus a black surface is an excellent emitter as well as an excellent absorber. If the same surface is silvered, it becomes a poor emitter and a poor absorber.

On the other hand, a light shiny surface is a poor absorber and poor emitter of infrared radiation, but they are good reflectors of radiation. So to keep house cool in hot countries, the houses must be painted in white or light colors.

This painting bring the idea that a surface can be intentionally painted or coated to achieve a particular or needed characteristics of absorption, Reflection or transmitted.

Reflection or transmission. Such coatings can either be in thick or thin film form, or in Nano particle form. A material with high absorbance and low emittance properties that is applied to or on the surface of solar absorbers create what is known as **Selective Surface or Coatings.** Selective Surfaces take average of the differing wavelengths of incident radiation and the emissive radiation from the surfaces and coatings, the wavelength of incident radiation from the absorbing of over 90%. For most surfaces and coatings, the wavelength of incident radiation matters because wavelength determine the amount of energy that is transmitted. Some materials are therefore designed to absorb radiation in one range of wavelengths very efficiently say the short wavelength, while they may be reflective in longer wavelength range.

Apart from selective absorption and emission, surfaces can also selectively reflect or selectively transmit light of certain frequencies. Thus, a surface like green leaves might reflect green (which is the color of leaf that we see) while absorbing all other frequencies. Another surface might selectively transmit blue light while absorbing all other frequencies of visible light. The manner in which visible light interacts with an object's surface is dependent on the frequency of the light and the nature of the atoms of the object.

Selective absorption of a particular light wave occur because the frequency of vibration of the light wave marches the frequency of the vibration of the atoms of the materials receiving the radiation. If their frequency do not march, then they will selectively absorb different frequency of visible light. Reflection and transmission of light waves occur because the frequencies of the light waves do not march the natural frequencies of the vibration of the objects, hence they do not vibrate in resonance.

If the object is transparent, then the vibration of the electrons is passed onto neighboring atoms through the bulk material and re-emitted on the opposite side of the object. Such frequencies are said to be transmitted. If the object is opaque, then the vibrations of the electrons are not passed from atom to atom through the bulk of the material. Rather, the electrons of the atoms of the materials vibrate in short period of time and then re-emit the energy as reflect light wave. Such frequencies of light are said to be reflected.

Mr. Vice Chancellor Sir, even though I have researched in various areas of Solar Energy Interactions as enumerated above, my main focus and core areas of research is Solar Energy Interactions with solar selective coatings, thin films and new materials that were fabricated, developed and characterized. These materials can be applied in different areas of solar energy applications for human comfort and development. These are;

1. Visible Transmitting Films (Vtf) like Manganese and Ferrous halides ($SnBr_2$, SnI_2, $MnBr_2$, FeI_2), and Ag_2S thin films with high visible transmittance, high ultraviolet absorbance and high infrared reflectance. These properties shows that these films are coated on transparent glass doors and windows of buildings, they are capable of allowing the transmission of only visible light band of the solar spectrum through doors and windows for day lighting in the buildings of solar radiation from entering into buildings. The implication of thin is that the indoor temperatures of such buildings will be reduced thereby achieving natural air conditioning without the use of AC, while still maintaining good illuminance level in those for people to still see very well. Thin is an important film in building and architectural physics.

2. Solar Transmitting Films (STF) or Solar Anti-Reflecting Films (STF or SAF). These films have high solar (UV - VIS -

mr) transmission and can be used to transmit and anti-reflect the solar spectral range (i.e. 0.3 /um to 0.7 /um range). This film can be applied as anti-reflection coating for solar photovoltaic modules for generating solar electricity. These films include CuI, CuBr and very thin PbS.

3. Infrared Transmitting Spectral Splitting Films (IRTSDS) Such as thick coated PbS, Ag_2S and FeI_2. These films allow complete visible absorption but transmits highly in the infrared segment of the spectrum and can be used as dark mirror coating that can be used as greenhouse glass for agricultural purposes. FeI_2 films could also be used as chromogenic glasses since they exhibit color change with respect to transmitted and reflected lights.

Also, depending on the film thickness, a single film like PbS, Ag_2S and FeI_2 can be used in more than one device application.

4. Trans heat highly coated CdS, Ag_2s, NiS, PbS, MnS, CuS and CuSe films with high electrical conductivities high solar absorption coupled with appropriate band gap range combine to make these films candidates for photo voltaic power generation (solar cells)

5. Transparent PbO, ZnI_2 and CoI_2 coating with moderate transmission in solar region, band gap corresponding to visible wavelengths or photon energy coupled with high electrical conduction make them good candidates for application as transparent electrodes that can located on the PV solar cells to serve as transparent contacts for the solar cells. Reflection or transmission. Such coatings can either be in thick or thin film form, or in Nano particle form. A material with high absorbance and low emittance properties that is applied to or on the surface of solar absorbers create what is known as

Selective Surface or Coatings. Selective Surfaces take average of the differing wavelengths of incident radiation and the emissive radiation from the surfaces and coatings, the wavelength of incident radiation from the absorbing of over 90%. For most surfaces and coatings, the wavelength of incident radiation matters because wavelength determine the amount of energy that is transmitted. Some materials are therefore designed to absorb radiation in one range of wavelengths very efficiently say the short wavelength, while they may be reflective in longer wavelength range.

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6. Semitransparent PBI_n and PBI_2 spectral splitting films with high infrared reflection can be used to split and separate solar region (uv-vis) from the infrared region.

The uv-vis can be used for photovoltaic power generation while the infrared part can be used for photo thermal heating purposes.

7. SnO and films were found to have an Opto-electronic properties which make them suitable in opto electronic industry.

8. Other films that were studied did not show any significant properties that could make them candidates of any of the above applications. Nevertheless the one that show significant properties can be used in the four important strategic device developments namely:

i. Energy control and regulation in architectural and building physics
ii. Photo-thermal heaters for green house agriculture
iii. Photo-voltaic power generation panels and contacts.
iv. Opto-electronic device applications films.

Mr. Vice Chancellor Sir, the interesting thing about the production and fabrication of these very important films is the fact that these films can be grown or fabricated with very simple., easy to replicate, large area deposition possibility and cost effective method of thin film production called the Solution Growth, or Chemical Bath Deposition Techniques which can be done even in the comfort of every ones home if the deposition procedures are optimized. In a paper titled the application of thin film fabrication technology for solar energy devices in school curriculum, I advocated the inclusion of this technology in secondary school curriculum to enable even secondary school students learn and use the technology.

The work sof Okujagu (1992, 1997, 1999) and Okeke (1997, 1998, 2000), Janje and Okujagu and Igbudu and Uso and Okujagu(2014) are all on growth, fabrication and characterization of thin film selective surfaces.

6.6 INTERACTION OF MRADIATION WITH BUILDING FACADES AND OTHER PHOTOTHERMAL ENERGY DEVICES

6.6.1 INTERACTION WITH BUILDING FACADES: When solar radiation interacts with opaque building facades (made up of all building envelopes - Roof cover, outer walls and windows and doors), radiation is usually absorbed by these materials and radiated into the building which increases the indoor temperature of the building

During daytime and hot season. On the other hand, at night or in cold season, these facades transports the heat inside the building to balance the temperature differences as the outdoor environment is now lower in temperature than the interior.

The transparent part of the building loses too much heat in colder regions and during the nighttime. But in hotter/warmer regions, the transparent facade causes excess heat gain during the day which will add considerably to the heating source of such buildings. To redress this build along or in such a way as to gain little or no heat during hot season and day time, while gaining heat during season as well as night time.

Another strategy is to ensure that the transparent facades (windows and doors) is well coated with materials that will allow them gain as much heat during cold (winter) season/climate and in the time, the emphasis should be on how to reduce heat. Base on thin cold climate and season, the coating should receive as much heat as possible without losing any heat. Exactly the opposite is applicable for hot climate and season. Here, the coating should reduce admission of solar radiation into the building in summer or day time, and the glass should be capable of not radiating from outside into the building. This can be achieved with the solar transmitting films already. (VTF) mentioned. The main issue is this case, is the maintenance of day lighting in the building interior. Daylight regulation strategies were attended by Okujagu and Arogba (2008) and Okujagu and Okoses (2011). It was found that transparent glass on the roof to light dark interior regions), using appropriate window shutters and appropriate transparent window and door coatings can be effectively used to create appropriate day-lighting in buildings to improve the wellbeing and comfort of the dwellers in such circumstances.

6.6.2 Other Photo thermal Devices and Other Renewable Energy Application: Mr. Vice Chancellor Sir, My research work also took me to the investigation of the application of solar energy applications in the areas of the construction of the following devices.

- Solar flat plate hot water heater for heating hot water for domestic use.
- Solar saline pond for process heating of water collage industries.
- Solar still for the purification or desalination of saline or impure water to produce potable water.
- Solar flat plate cooker and solar parabolic cooker for outdoor cooking of various food items.
- Solar crop dyer and solar food (cray fish & fish) dryer.
- Biomass briquetting device
- Charcoal, sawdust and wood stoves
- Bio gas stove.

CONCLUSION:

Mr. Vice Chancellor Sir, let me conclude this panorama of solar interactions by saying that solar energy no doubt is the ultimate alternative energy source that is capable of replacing fossil fuel which is complete mitigating the pollution caused by fossil fuel energy and its attendant negative effect of depleting ozone layer and the production of greenhouse gasses both of which are the leading causes of global warming and climate change. The use of solar energy for our energy supply and regulation will prove to be the only panache for preventing deforestation that leads to the reduction of our precious vegetation (carbon sink), a solar energy device is also recommended because it is the leading renewal energy source that is clean, safe and sustainable for present and future generation.

Mr. Vice Chancellor Sir, may I intimidate you that my latest research endeavors are in the areas of;

- Influence of solar activities in Radio communication
- Physics of colloids solution and suspensions materials.

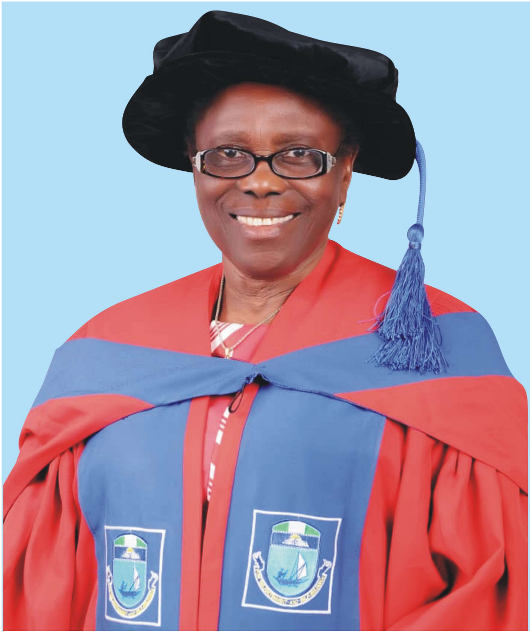
Let me say Mr. Vice Chancellor Sir that the outcome of these researches will be the subjects of my valedictory lecture in a few year time.

RECOMMENDATION

Mr. Vice Chancellor Sir, it may interest you to know that most of these researches were carried out outside this university because there is no laboratory established for solar energy in the department of physics of university of Port Harcourt. Apart from the films that can be grown or deposited anywhere provided the chemicals and containers for their production are available here. Starting from my PhD and those of my students that I have supervised at all levels, we go from one University to research centers nationwide to characterize our films and designate our providers. Let me therefore recommend Mr. Vice Chancellor Sir that a fully equipped solar energy research laboratory and center established in the University of Port Harcourt to the Federal Government to serve South-South region. The production of some of these simple devices can be in such contrast to reduce our over dependence on fossil fuel usage.

I also recommend that some of simple technology should be incorporated into the introductory technology curriculum in Secondary Schools. This will help in bringing these important but simple appliance to grass roots.

CITATION



PROF. CHARITY UKPOK-AWAJI OKUJAGU

(FNIP, FSESN, MMSN) B.Sc (UNIPORT), M.Sc

EARLY LIFE AND EDUCATION:

Charity Ukpok-Awaji Okujagu was born on 24th November, 1952 to the Utong Royal Family of ancient Ilotombi Town, Andoni Local Government Area, of Rivers State, and married on 3rd November 1984 to Late Venerable Professor Thompson Ngeri Okujagu of Okujagu-Ama in Okrika LGA of Rivers State, making her a November lady and a True Rivers woman.

Professor Charity Okujagu lost her father at the tender age of three and was left in the care of her mother (now late), and elder sister Mrs. Naomi Israel Etete (a primary school Teacher) who enrolled and saw her through her primary and half way through her secondary school and could not continue training her due to the loss of their means of livelihood because of the Nigerian civil war. God's grace and infinite mercies brought her in contact with some benevolent Canadian Missionary Teachers who were teaching in her school at BMGS, Bori where her sister registered her after the war to conclude her secondary education. These missionaries sported her brilliance and would not let such a brain to be wasted due to lack of funds, so they took her up and saw her through the last two years of her secondary education. This became the beginning of many marvelous works and interventions of God in Charity's life. With constant transfer and movement of her elder sister, Charity ended up schooling in at least four primary schools, yet the brilliant Charity spent only five years completing her primary school education that normally took eight years at that time due to the fact that she had triple and double promotions two times respectively, due to her exceptional brilliances. But for the intervention of her elder sister who refused a third double promotion, Charity would have gone through the primary school in three or four years only. Lack of funds prevented her from enrolling into the secondary school when she finished primary school in 1963, so she had to wait about four years in the house for her elder sister to gather enough money for her to go back to school.

This became possible in 1967 when she got enrolled at Etche Girls Secondary School Umuola, Etche, but was cut short for another three years due to Nigerian Civil War. When the war was over, she was reenrolled at BMGS, Bori where she finished in 1973 with flying colours with a grade one certificate in those days, despite the health challenge she had at that time.

Having been given this head start in life up to secondary school level by her mother, sister and Christian parents, Professor Okujagu was now well equipped to take her destiny in her hands with or without any external aid. By God's special design again, the young school certificate holder secured a job as a tutor at the Marrian High School, Bane, Ogoni where she taught Mathematics, Physics and Chemistry. At Bane she mentored many young girls who are now very prominent people in the society. From Bane, she was then transferred to Government Secondary School Ngo, Andoni also as the first science teacher in Physics, Mathematics and Chemistry to brush up the pioneer secondary school students in Obolo who are now big men and women in Obolo nation. During this brief teaching experience, Professor Okujagu saved up funds to sponsor herself in the university when she gained admission to study Physics in the Unique Choba University (Uniport) as one of the pioneer students and became one of the pioneer graduates of Unique class 81 of Unique Uniport (UU81).

Since there was no Engineering course in Uniport then, she was forced to major in Physics which was closest to the Industrial Engineering course she had planned to study abroad but could not do so as she did not make the scholarship list both of the Federal and State government. This is another miraculous handiwork of God Almighty in her life. When this happened, Charity was not quite happy about it but sooner, she came to understand and accepted it as God's plan for her life.

After graduation and the compulsory NYSC, she proceeded to the University of Ibadan to acquire her Master's Degree in Meteorology due to the fact that she was employed as a Meteorologist by the Federal Ministry of Aviation. Her marriage to Venerable Professor T. N. Okujagu in 1984 made her to disengage from the ministry of Aviation to pick up a job with the University of Port Harcourt as an Assistant Lecturer in 1985. Having changed her carrier line by this shift, she left family responsibilities briefly and enrolled for the Ph.D programme at the University of Nigeria, Nsukka, in 1988 where she obtained her Ph.D in Solar Energy Physics in March, 1992.

ACADEMIC POSITIONS AND CONTRIBUTIONS:

Professor Okujagu now an established physicist, and academics in a rare field, rose through the academic ranks to become a professor of Solar Energy Physics in 2010, surmounting all odds in her way, including loss of her dear husband and many health challenges. It must have been a rough climb for her as she is usually the only girl or lady in her class or department from her secondary school days to her last level of education and early carrier years. Having paved the way, she is happy to have some of her female colleagues join her in the field and she is no longer seen and considered an “intruder” in men’s world. Professor Okujagu has contributed immensely to the body of knowledge in her field through her personal research publications, teaching and supervision of under graduates and post graduate (Master’s and Doctorate) students of which she has graduated up to 12 M.Sc, 6 Ph.D including few that will soon graduate and several under graduate students as well.

Her research area covers Solar Energy Systems and Conversion processes, Solar Radiation and Environmental /Atmospheric processes, Solar Energy Materials and Bio Materials for Energy applications to create conducive and sustainable environment, Nano Materials/Nano Technology/Thin Film Technology for Energy applications, Climate change, Global warming/ heat island mitigation models and metrological phenomena and processes. Professor Okujagu has developed Thin Films and Nano particles for temperature reduction in houses, constructed several solar energy devices such as solar flat plate collectors and concentrators for domestic hot water heating, solar cookers, solar stills for water purification, solar ponds for process water heating, solar dryers, Thin film selective surfaces etc. She has over 50 journal articles to her credit and has co-authored books with her late husband and her collogues. She has also attended several conferences seminars and workshops both nationally and internationally and she is also a speaker in some of these fora.

ACADEMIC / PROFESSIONAL POSITIONS AND AWARDS

Professor Okujagu has held the following academic and professional positions: Deputy Provost College of Natural and Applied Science/Associate Dean, Faculty of Science Uniport (2012-2016), Visiting Professor Rivers State University (2010), Federal University Otuoke (2017), External Examiner for both under graduates and graduates in Uniben, UNN, Covenant University and Assessor for professorial promotions for several Universities, membership of several University of Port Harcourt Senate, Faculty and Departmental Committees, and member of Exco in Nigeria Institute of Physics, Solar Energy Society of Nigeria and Nigeria Metrological Society.

She has served the Rivers State Government as Special Adviser to the Governor Peter Odili on Science and Technology. She has also served as chairman of Accreditation panel to some Nigerian Universities. Professor Okujagu is a member of the following National and International Bodies, International Solar Energy Society (ISES), World Energy Counsel (WEC) Nigerian Chapter, America Solar Energy Society (ASES), Nigeria Institute of Physics (NIP), Solar Energy Society of Nigeria (SESN), Nigerian Metrological Society (NMS), Physics Writer Creation Series (PWCS), Renewable and Alternative Energy Society of Nigeria (RAESON), Women in Energy Association of Nigeria

(WEAN), Women in Physics (WP), Nigeria Association of Women in Academics (NAWACS)

AWARRDS AND HONOUR

Professor Charity U Okujagu as a woman of many part has bagged many honours from many professional, Religious and Social circles including the followings; Follow Solar Energy Society of Nigeria, Fellow Nigeria Institute of Physics, Consulting Editor American Biographic Institute, Listed in Contemporary Who is Who by American Biographic Institute, Honorary fellow, Institute of Corporate Administration, Ambassador of Peace by International Federation of World Peace, Pillar of Nation Building Award by Institute of Human and Natural Resources, Silver Membership Award by International Solar Energy Society, Hall of Fame Membership of the Faculty of Science, University of Port Harcourt, Long Service Award by University of Port Harcourt, Life Membership Award National Union of Andoni Students (NUAS), Award of Excellence by Nigeria Fellowship of Evangelical Student (NIFES), Distinguish Membership Award by University of Port Harcourt Alumni Association, Award of Excellence by Women Guild, Niger Delta Diocese, Special Mothers Award by (MU/WG), Dioceses of Okrika, Vessel of Encouragement Award by computer students of Ven Professor T.N. Okujagu Foundation for Ethnics and Learning, Long Time Service Award by Great Commission Movement of Nigerian, which is the latest in her collection of awards.

Professor Okujagu is either a Chairman, Council Member or Founder of many Organization such as; Trustee member of Club 401 of Port Harcourt, Great Commission Movement of Nigeria (GCMN) Jos, Luke Initiative for Scriptural Translation (LIST) Jos, Agape Centre for Development (ACD) Jos, Board Chairman for Prayer Summit Network (SPN), Patron Kings

Choral Voices (KCV) Port Harcourt and Founder/Board Chairman Hissoufac Charity Foundation and Ven Professor T.N. Okujgu Foundation for Ethnics and Learning. She is also a governing council member for Centre for NGO'S and Citizen's engagement (CNC engage), The Obolo Consultative Council and Secretary (BOT) of Obolo Language and Bible Translation Organization (OLBTO) and Obolo Bilingual Education Centre (OBEC).

Professor Charity Okujagu is a first in many areas of endeveour. She is the first graduate (SSCE, B.Sc, M.Sc and Ph.D) in her community of Ilotombi, first female physics graduate and professor in Andoni and Rivers State. She is also the first Solar Energy professor in Andoni (Obolo) and Rivers State. Professor Okujagu is an academics and physics Iron Lady being in a rare field of study where even men dread to thread. A woman of many parts, a physicist of physicists, a mentor to young and old, males and females, the lovable and unlovable, a good team player and academic giant and guru, a high and single minded flyer, and impersonation of integrity and true humanity, a truly born again child of God and lover of Rivers State, Nigeria and Africa, a prayer warrior, preacher and follower of her Lord and personal Saviour Jesus Christ.

Please join me to welcome an accomplished physicist, a mother of two great children (Diepiriye C. Okujagu and Mrs. Ibifubara Iyalla) and grandmother of Princess and Daniel Iyalla, a veritable rare gem in a men's world, a tried and tested Solar Energy Physicist and a true and worthy daughter of Obolo, Professor Charity Ukpok-Awaji, Awajioboemi Okujagu to deliver her lecture.

Professor Ndowa S.E Laale