Quest for Internet

In the fifth installment of our weekly series at emeagwali.com, we focus on Philip Emeagwali's 1982 discovery of how to use the atmosphere as a metaphor for a petroleum reservoir and, in turn, discover new equations and algorithms. That discovery laid the foundation for his 1989 discoveries of how to simulate a petroleum reservoir on a supercomputer that was connected like a superinternet (a word Emeagwali coined).

as the breakthroughs. It took me ~~15~~ fifteen years of cumulative discoveries although although 1989 was ~~my defining year~~. the year those outside my close circle understood what I did. That was where I reached the climax of my imaginative journey and a soaring flight into our children's children's eight super continent, or the internet of ~~tomorrow~~ the future. I envisioned it as an electronic cloth, a Super Brain, that will enshroud ~~over~~ their Earth Mother. and maybe worshipped as their Super Being. or digital God. eight_continent_super_internet_of

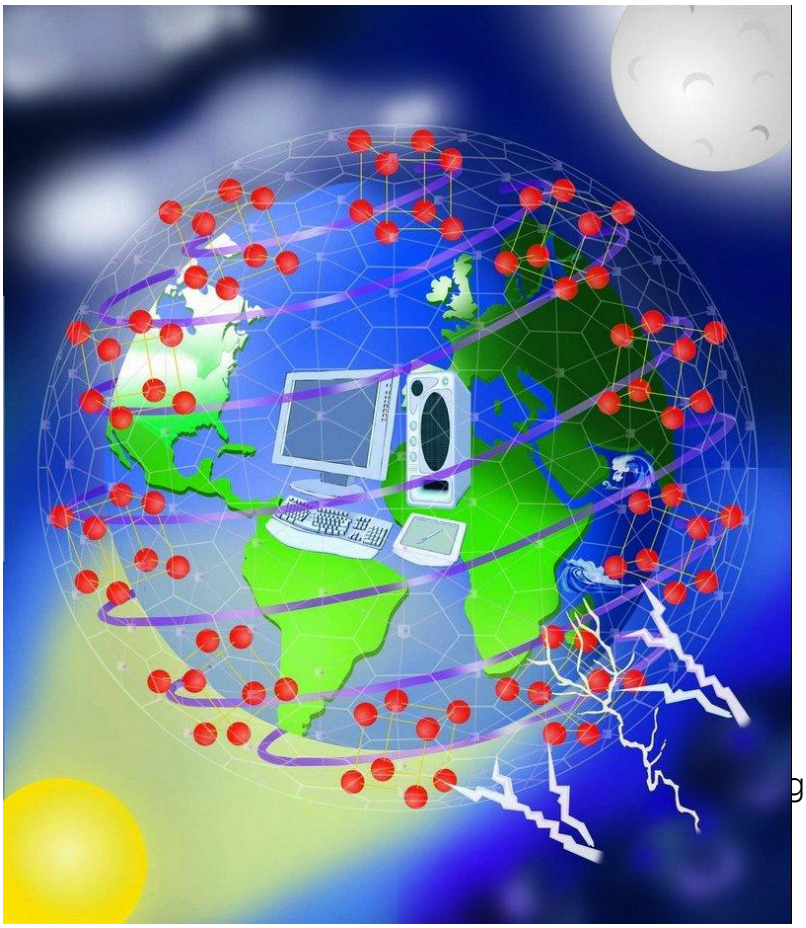
My Superinternet is in the Wind

by Philip Emeagwali

Transcribed and edited from a lecture delivered by Philip Emeagwali. The unedited video is posted at emeagwali.com.

The Second Law of Motion is a 330-year-old story that first described the motion of the planets. I refocused on it in my December 1982 lecture to geologists and meteorologists that was held in Washington, D.C. In 1982, I was more at home in meteorology than in geology, so I relocated the story from the earth's atmosphere to its subsurface and thus reinvented the iconic Darcy's formula.

That transition was a defining moment in which I discarded my atmospheric filter and saw reservoir simulation differently from geologists, and it brought a sudden burst of clarity in my understanding of the century-old formulas. That clarity led to my discovery that the sets of coupled partial differential equations governing weather forecasts should be equivalent to those used in reservoir hindcasts because both were derived from the Second Law of Motion.



I saw that it is incongruous for the weather equations to be classified as hyperbolic, while the reservoir equations are parabolic. My defining moment was when I realized that the gas and water flowing inside a reservoir are mathematically equivalent to the air and moisture flowing in an atmosphere. Since both sets of coupled equations are restatements of the Second Law,

both should be hyperbolic. I resolved the incongruity by reformulating and reinventing the reservoir equations so that they were hyperbolic as well as mathematically equivalent to the ones used to forecast the weather.

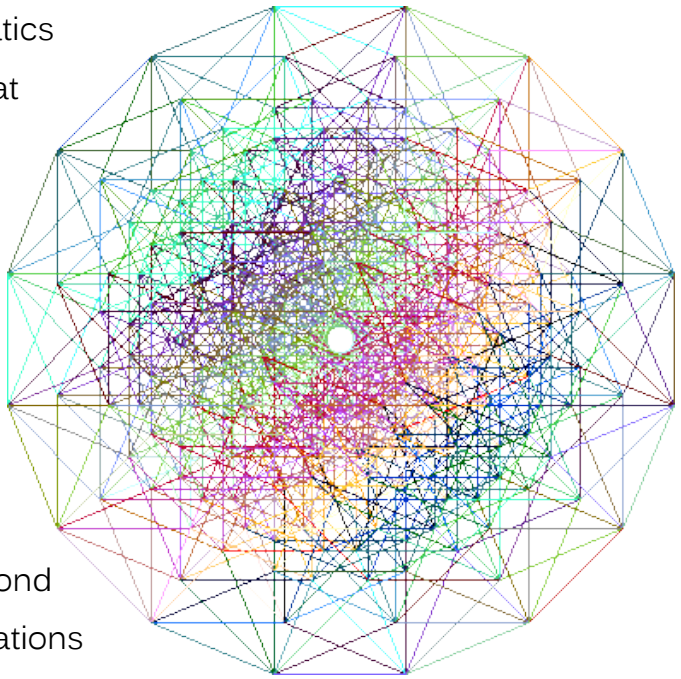
Rachel Bonas, myself and Sheela Chand at an outing following my University of Idaho, Moscow, College of Engineering Banquet Lecture of February 21, 2008

The Second Law of Motion is a law because it is true *a priori*, and holds anytime and anywhere. It is true in distant galaxies as well as in our oil reservoirs. It is an axiomatic, factual statement about how everything moves in our universe and is called a "universal law" because it applies to all objects in the universe.

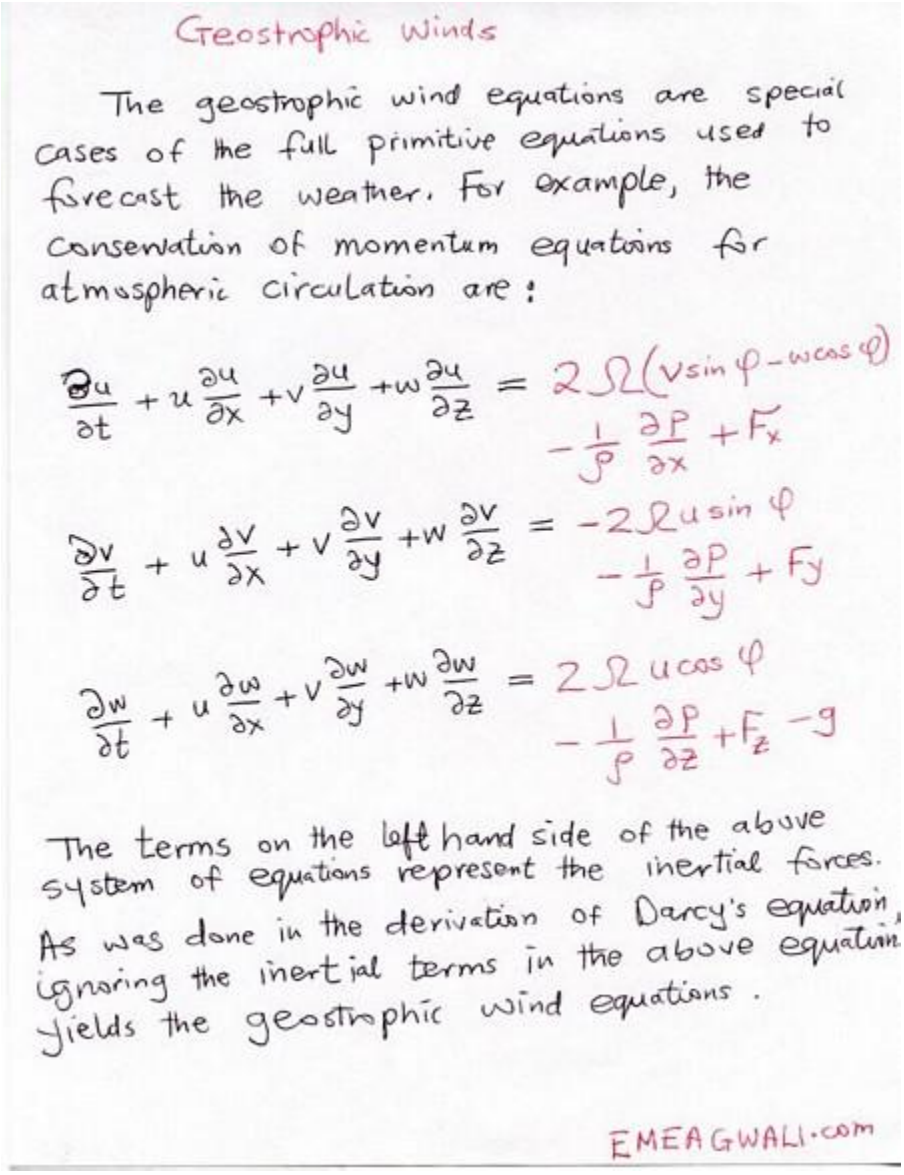
We use it for predictions because forecasts and hindcasts based upon the Second Law of Motion are as reliable as the sun rising in the east. It is considered the most

important discovery in physics and has been used for countless simulations, such as to forecast the weather, hindcast the petroleum reservoir, and simulate nuclear explosions.

The technique of calculus is to mathematics what the laws of motion are to physics. Calculus is the crown jewel of mathematics that belongs to the group of great discoveries that includes Pythagoras theorem and the theory of evolution. At its core, calculus is about change and motion, and it is used to forecast the changes in the motions of the air and moisture in an atmosphere and that of the oil, water, and gas in a reservoir.



At its most advanced level, calculus is a partial differential equation (PDE) that encodes the Second Law of Motion. My favorite PDEs are the six equations for weather forecasting, which I later reinvented as nine equations for reservoir hindcasting. I coupled these equations to additional equations that encoded other laws, such as the law of conservation of mass. The weather became my metaphor for the reservoir and inspired me to discover equations and algorithms for supercomputers that are connected as an internet.



Geostrophic Winds

The geostrophic wind equations are special cases of the full primitive equations used to forecast the weather. For example, the conservation of momentum equations for atmospheric circulation are:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = 2\Omega(v\sin\varphi - w\cos\varphi) - \frac{1}{\rho}\frac{\partial P}{\partial x} + F_x$$

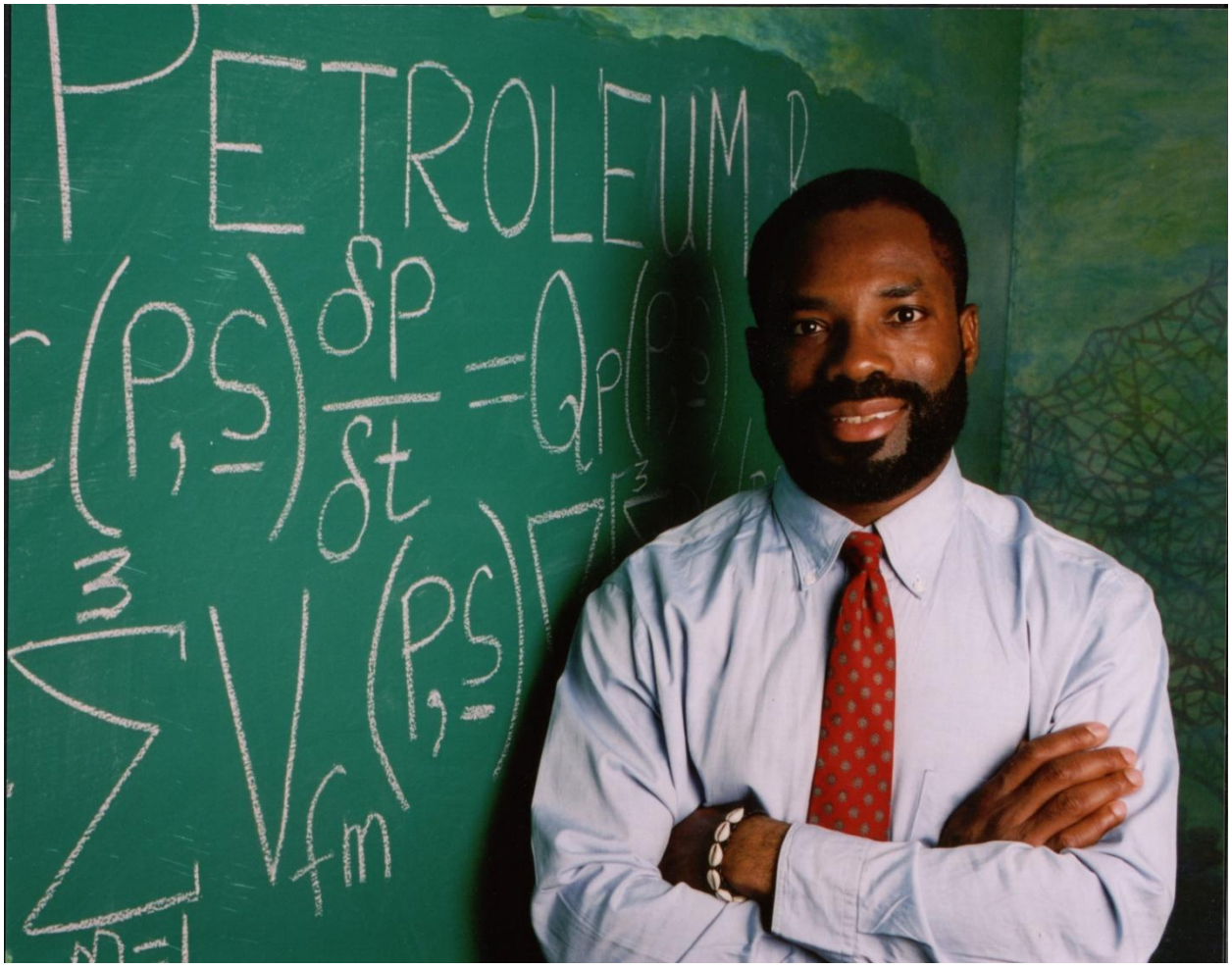
$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -2\Omega u\sin\varphi - \frac{1}{\rho}\frac{\partial P}{\partial y} + F_y$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = 2\Omega u\cos\varphi - \frac{1}{\rho}\frac{\partial P}{\partial z} + F_z - g$$

The terms on the left hand side of the above system of equations represent the inertial forces. As was done in the derivation of Darcy's equation, ignoring the inertial terms in the above equation yields the geostrophic wind equations.

EMEAGWALI.com

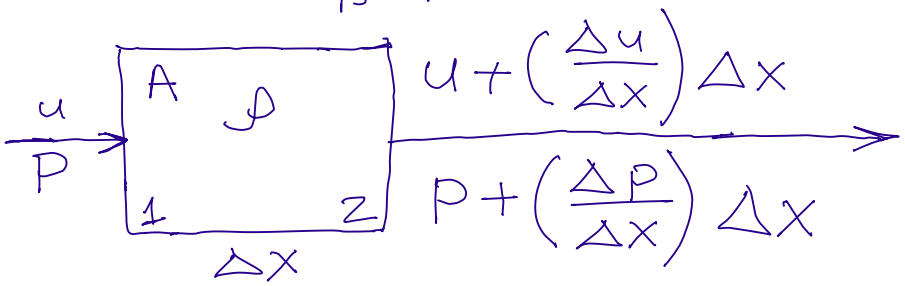
I made discoveries in weather forecasting using supercomputers. This is a memo I forwarded to a meteorologist explaining the calculus of weather forecasting. (Handwriting of Philip Emeagwali, circa 1989)



I write on the board the actual equations used by Exxon (now Exxon Mobil) to simulate the flow of oil, water, and gas inside its reservoirs.

I argued that mathematics is based on reasoning, not reckoning. I discovered that the reverse holds for engineering. As a result, petroleum engineers did not understand the context of their reservoir simulators. From reasoning, I discovered a critical error in the 160-year-old equations used to extract oil. Errors are hard to correct, but a century and a half old error overlooked by seven generations of mathematicians has more lives than a cat.

Conservation of Momentum
Steady, one dimensional flow



Newton's Second Law of Motion
Force = Mass x Acceleration

$$F = ma = m\frac{\Delta u}{\Delta t}$$

$$-\left[(PA)_2 - (PA)_1\right] = m\frac{u_2 - u_1}{\Delta t}$$

$$-\left[\left(P + \left(\frac{\Delta P}{\Delta x}\right)\Delta x\right)A - PA\right] = m\frac{u + \left(\frac{\Delta u}{\Delta x}\right)\Delta x - u}{\Delta t}$$

$$-\left(\frac{\Delta P}{\Delta x}\right)\Delta x A = m\left(\frac{\Delta u}{\Delta x}\right)\frac{\Delta x}{\Delta t}$$

Substituting $m = \rho \Delta x A$ and $\frac{\Delta x}{\Delta t} = u$ yields

$$-\frac{\Delta P}{\Delta x} = \rho u \frac{\Delta u}{\Delta x}$$

Shrink domain to differential sizes & gradients become differentials

$$-\frac{dP}{dx} = \rho u \frac{du}{dx}$$

Excerpts from my research notes that explained the century and half old mathematical error. I discovered and corrected the error the critical equations used to extract oil by emphasizing insight over formulas, explanations over assertions, critical thought over methodology, and curiosity over virtuosity. I

corrected the critical error with equations founded on ‘only if’ rather than ‘if only’ the inertial forces did not exist. [emeagwali.com]

2nd Law of Motion

Force = mass x acceleration, F=ma

Forces are unbalanced

↓

There is acceleration

↙ ↘

Acceleration proportional to net force

Acceleration inversely proportional to mass

Coordinate system w.r.t. Earth:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{r\cos\phi\,\partial\lambda} + v\frac{\partial u}{r\partial\phi} + w\frac{\partial u}{\partial r} - \left(2\Omega + \frac{u}{r\cos\phi}\right)(v\sin\phi - w\cos\phi) + \frac{1}{\rho}\frac{\partial p}{r\cos\phi\,\partial\lambda} = F_\lambda$$

Summing, balancing forces on control volume:

$$\rho\,dx\,dy\,dz\,\frac{Du}{Dt} = \rho\,dx\,dy\,dz\left(\frac{\partial u}{\partial t} + \frac{dx}{dt}\frac{\partial u}{\partial x} + \frac{dy}{dt}\frac{\partial u}{\partial y} + \frac{dz}{dt}\frac{\partial u}{\partial z}\right) = \rho\,dx\,dy\,dz\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right)$$

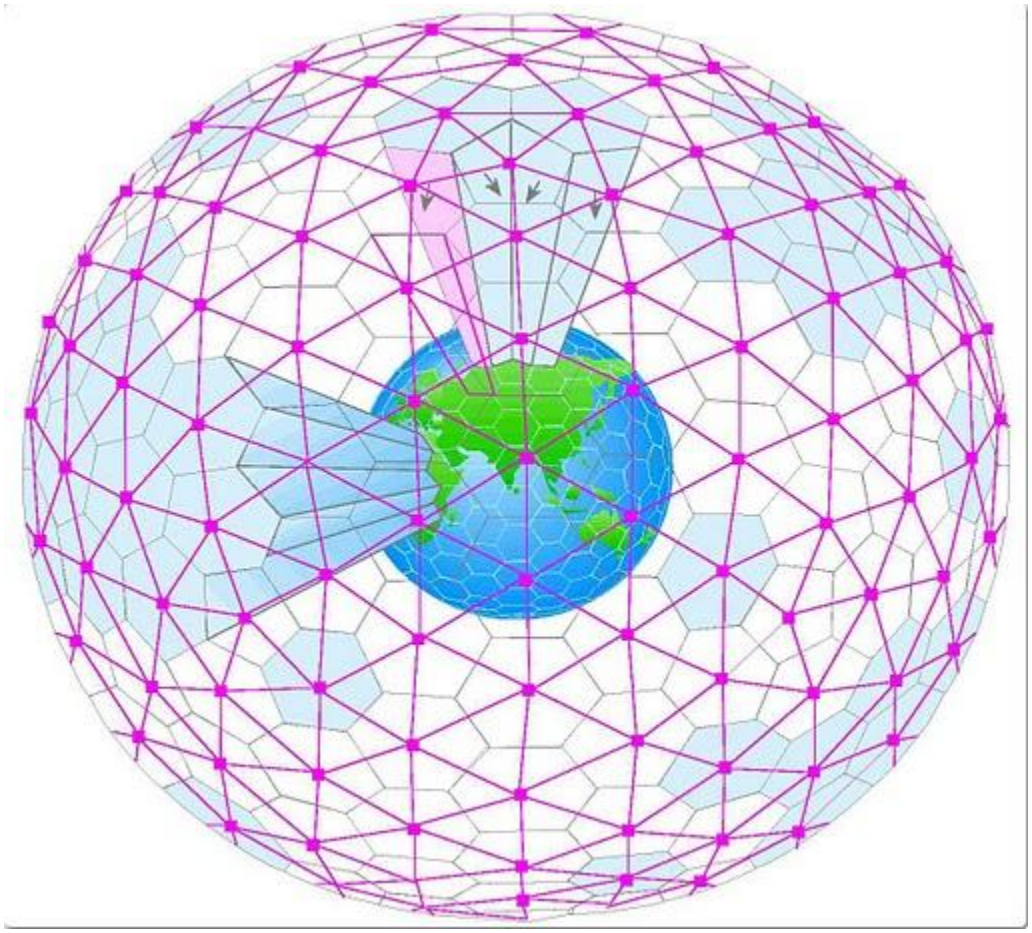
Excerpts from my first test-bed code meteorological forecasts that used the Second Law of Motion. If you are a research mathematician, specializing in Numerical PDE, you will notice I used unfamiliar notations. I invented these unconventional notations because my unorthodox supercomputer was connected as an internet.

$$\frac{{}^{+1}_{+1,0}\mathbf{u} - {}^{-1}_{+1,0}\mathbf{u}}{2\Delta t} = -\frac{{}^{cs,0}_{+2,0}\mathbf{H} - {}^{cs,0}_{0,0}\mathbf{H}}{2\Delta x}$$
$$+\frac{1}{8}\left({}^{cs,0}_{+1,+1}\mathbf{Z} + {}^{cs,0}_{+1,-1}\mathbf{Z}\right)\left({}^{cs,0}_{+2,+1}\mathbf{V} + {}^{cs,0}_{0,+1}\mathbf{V} + {}^{cs,0}_{+2,-1}\mathbf{V} + {}^{cs,0}_{0,-1}\mathbf{V}\right) \tag{15.4}$$

$$\frac{{}^{+1}_{0,+1}\mathbf{v} - {}^{-1}_{0,+1}\mathbf{v}}{2\Delta t} = -\frac{{}^{cs,0}_{+2,0}\mathbf{H} - {}^{cs,0}_{0,0}\mathbf{H}}{2\Delta y}$$
$$+\frac{1}{8}\left({}^{cs,0}_{+1,+1}\mathbf{Z} + {}^{cs,0}_{-1,+1}\mathbf{Z}\right)\left({}^{cs,0}_{-1,+2}\mathbf{U} + {}^{cs,0}_{-1,0}\mathbf{U} + {}^{cs,0}_{+1,+2}\mathbf{U} + {}^{cs,0}_{+1,0}\mathbf{U}\right) \tag{15.5}$$

$$\frac{{}^{+1}\mathbf{P} - {}^{-1}\mathbf{P}}{2\Delta t} = -\frac{{}^{cs,0}_{+1,0}\mathbf{U} - {}^{cs,0}_{-1,0}\mathbf{U}}{2\Delta x} - \frac{{}^{cs,0}_{0,+1}\mathbf{V} - {}^{cs,0}_{0,-1}\mathbf{V}}{2\Delta y} \tag{15.6}$$

The above algorithms are exemplary and my nine algorithms were examples.



Conservation of Momentum Navier-Stokes Equations

$$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z}$$

$$= -\frac{\partial p}{\partial x} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right]$$

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z}$$

$$= -\frac{\partial p}{\partial y} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}\right]$$

$$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z}$$

$$= -\frac{\partial p}{\partial z} + \frac{1}{Re_r}\left[\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right]$$

(x, y, z) : coordinates
t : time
ρ : density
p : pressure
Re : Reynolds Number
(u, v, w) : velocity components
τ : stress
q : heat flux
Pr : Prandtl number

My abstract equations were often misunderstood, the original discoveries escape the public, and the invention is reconstructed and reinvented by the readership.15

Conservation of Mass and Energy
Navier-Stokes Equations

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

$$\frac{\partial(E_T)}{\partial t} + \frac{\partial(uE_T)}{\partial x} + \frac{\partial(vE_T)}{\partial y} + \frac{\partial(wE_T)}{\partial z}$$

$$= -\frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z}$$

$$+ \frac{1}{Re_r}\left[\frac{\partial}{\partial x}\left(u\tau_{xx} + v\tau_{xy} + w\tau_{xz}\right)\right.$$

$$+ \frac{\partial}{\partial y}\left(u\tau_{xy} + v\tau_{yy} + w\tau_{yz}\right)$$

$$\left. + \frac{\partial}{\partial z}\left(u\tau_{yz} + v\tau_{yz} + w\tau_{zz}\right)\right]$$

$$- \frac{1}{Re_r Pr_r}\left[\frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} + \frac{\partial q_z}{\partial z}\right]$$

Mathematics is pursued through symbols, not words. The above is a typical page from my mathematical research notebooks. For me, there was an organic interplay between physics and mathematics, but my goal was to broaden mathematics from the practical to the precious. It's

value increases when maths migrates from the blackboard to the motherboard that is redefined as an ensemble of 65,536 sub-computers connected as an internet. The minute analyses to the micro level of all the equations and algorithms I developed consumed ten years of my life and over a thousand pages.

Date:	5/23/2006, 6:16 pm, GMT +6
Name:	ODOM UCHE.C <193.220.78.5>
Location:	OJODU BERGER, LAGOS
Number:	25

I TELL MY STUDENTS ABOUT AN AFRICAN WHO INSPIRES ALL OTHER AFRICANS AND MOST ESPECIALLY MYSELF,YOUR ACHIEVEMENTS SHOW THAT WITH HARDWORK GOD ON OUR SIDE WE CAN INNOVATE, YOU ARE MY SCIENTIFIC ROLE MODEL, I HOPE I CAN CONTRIBUTE TO KNOWLEDGE SOMEDAY ALSO...

Date:	5/23/2006, 5:38 pm, GMT +6

Name:	Mark Farquharson <68.105.234.158>
Location:	Hampton Va
Number:	24

This site is GREAT !!! I am 45 with a degree in Aeronautics. You have inspired me to go back to school for my masters.

Thank You

Date:	5/23/2006, 6:10 pm, GMT +6
Name:	ikeazor anieto <81.199.55.142>
Location:	onitsha ,anambra state nigeria
Number:	23

hi the greatest, i am very proud of u. do something for Nigeria, you know that the country is backward technologically.let make a deal.dial me on this no 234 806 387

1875.thanks	
Date:	5/22/2006, 9:29 pm, GMT +6
Name:	Somkene Mbakwe <62.56.236.20>
Location:	Port harcourt, Nigeria
Number:	22

I am proud of you Phillip. You are the pride of the entire black race. More power to your elbows.

I also would like to bring to your notice that millions of young and talented Nigerians are longing to meet you. Please we will be grateful if you'll create such a forum, where we can actually have a taste of you as one of our own.

I am number one.

kcbaks@ieee.org, kennyboy@computer.org.

Date:	5/17/2006, 1:01 pm, GMT +6
Name:	UZOH

	EKULIDE <81.23.204.229>
Location:	TINAPA,CALABAR,NIGERIA.
Number:	21

PHIL, IAM REALLY VERY PROUD OF YOU AND MUCH MORE AS A SHINING LIGHT TO THE BLACK RACE ESPECIALLY IBOS AND NIGERIANS.WELL DONE BIG BROTHER.

Date:	5/16/2006, 5:20 am, GMT +6
Name:	Daniel Taiwo Chaytor <85.31.48.65>
Location:	Freetown, Sierra Leone
Number:	20

Fight the good fight, brother, and keep up the excellent work. It's so refreshing to discover a modern African scientific

genius who is also Afrocentric. How come I didn't hear about you in 1989, when I was still an electrical engineering student? How come you weren't made Time mag's man of the year?

Date: 5/12/2006, 5:16 pm, GMT +6

Name: tosin bolaji <64.201.33.121>

Location: lagos nig

Number: 19

i'm proud to be identified with you as a nigerian.keep up the good work sir.

Date: 5/6/2006, 9:52 pm, GMT +6

Name: ikeazor anieto <81.199.55.142>

Location: onitsha, anambra state

Number: 18

i luv u more than u do .make an impact in

the lives of Nigerians. create a foundation. do something to aid the hopeless Nigerian youths.thamks
Date: 5/5/2006, 4:24 pm, GMT +6 **Name:** kester okpala <62.56.148.215> **Location:** Awka **Number:** 17
YOU HAVE MADE NIGERIANS PROUD.I AM SO MUCH ENTICED BY YOUR ACHEIVEMENTS IN LIFE.YOU ARE SOURCE OF INSPIRATION FOR YOUTHS OF OUR DAY.CHEERS.
Date: 5/5/2006, 3:33 am, GMT +6 **Name:** Fayomi Falade Aworeni <71.209.233.103> **Location:** Phoenix Arizona USA **Number:** 16

It has been my pleasure to know that such an inspiring individual was created by Olodumare. You have brought understanding to math to our youth when some believed they had no hope of accomplishing such tasks in this life time.

Date: 5/4/2006, 9:36 pm, GMT +6

Name: jon <67.189.76.200>

Location: portland oregon

Number: 15

Thank you for your website and all your work. Kene Chukwu for you.

Date: 5/3/2006, 8:59 pm, GMT +6

Name: Omotayo Daniel <67.163.50.234>

Location: Chicago, Illinois, USA

Number: 14

Hello

Your the best Nigerian

Date: 4/25/2006, 6:24 pm, GMT +6

Name: Ndu Eke <193.220.50.236>

Location: Adeola Odeku V/I, Lagos

Number: 13

Dear brother,
I am excited to know and read about you and your eternal achievements. I am particularly impressed with your communication ability in english and Igbo and think you are really great. God bless

Date: 4/15/2006, 11:29 pm, GMT +6

Name: igandan <216.139.189.66>

Location: olasunkanmi

Number: 12

you deserved more than to be on our Stamp, should be on our Currency. You are mine forever.

Date: 4/15/2006, 11:32 pm, GMT +6

Name: IGANDAN OLASUNKANMI <216.139.189.66>

Location: LAGOS STATE

Number: 11

YOU DESERVED MORE THAN TO BE ON OUR STAMP. YOU ARE TO BE ON OUR CURRENCY. YOU ARE MINE FOREVER.

Date: 4/14/2006, 4:43 pm, GMT +6

Name: Victor Balonwu <62.194.12.223>

Location: Amsterdam Netherlands.

Number: 10

Onitsha people are proud of you.Keep it up and God bless you.

Date: 4/6/2006, 6:05 am, GMT +6

Name: abodunrin saheed <209.159.175.199>

Location: ibadan nigeria

Number: 9

i am proud of being a nigerian and i know you would too.please try do something in nigeria because we are backward technologycally here and few people know about you here in your own motherland.

Date: 3/31/2006, 6:05 pm, GMT +6

Name: ikeazor anieto <80.78.18.64>

Location: onitsha ,anambra state Nigeria

Number: 8

i like u very much . u are sort of a hero 2 me.u are the world greatest scienctist .what have u done for ur country Nigeria ,what do u intend to do 4 the country since u know that the country is backward technologically. the onitsha youths are now very jobless. try to make positive impact to ur motherland. it seems that u like american more than Nigeria. thanks a million.

Date:	3/26/2006, 9:21 pm, GMT +6
Name:	Akin Akindahunsi <194.81.33.111>
Location:	Liverpool, UK
Number:	7

I'm proud of you as a Nigerian. Just knowing about your contributions to science is inspiring! Greater heights to Africans. I wonder how many Africans are making landmark achievements quietly

somewhere? What we need to figure out is how to use our intellect to improve the standards of living and quality of life back home - no equation seems to be working there! Cheers.

Date:	3/21/2006, 10:43 pm, GMT +6
Name:	Korim chidiebere <82.193.42.42>
Location:	Nigerian
Number:	6

Dr. Philip Emeagwli is the man i admire the most. i believe he is the moses of Africans. he did not only made us proud, but he left a laggacy warthy of emulation by all youth who want to succed in life. He also show them that Africans are superior only that Bad gorvernmene is reverging us.
though he might have lost hope in Nigeria but i want to tell him that he is owing many Nigerian the dept of comming home and show us the way up staies. i will like to

include him in my new book as one of those set aside to be emulated.

Date:	3/17/2006, 8:33 pm, GMT +6
Name:	Priscilla Busola Adegoke <64.12.116.196>
Location:	Dallas ,Texas
Number:	5

This is simply amazing! On a scale of 10 i think you deserve 10pts! I am so proud of you. I am a Radiology major at a college here in dallas. This is my first visit to your website, and i think you definitely need more publicity. Your speech was very moving and i think one way to encourage this younsters is to create scholarship opportuinities and offer them jobs back home like you mentioned. There are thousands of great minds out there who don't even have the chance to get into schools in Nigeria because of the fierce

competition.It is no longer a case of who is intelligent like it was in my father's days but it is now who you know and how much money you have, this very sad. I was a victim three times but now im a straight a student at my collegeiin Texas !

Date: 3/17/2006, 12:32 pm, GMT +6

Name: Ugorji Ogbonnaya (Njoku) <155.232.250.19>

Location: South Africa

Number: 4

We are proud of you. I think the whole world need to know you more. My prayer is that God will empower you more.

Date: 3/16/2006, 8:18 pm, GMT +6

Name: ikeazor anieto <216.226.225.50>

Location: onitsha

Number: 3

i luv u

Date:	3/10/2006, 9:25 pm, GMT +6
Name:	Lawrence Okoye <193.220.50.236>
Location:	Lagos Nigeria
Number:	2

Guy
You more publicity than you think.I will suggest you arrange a programme with DSTV in South Africa for a documentary on you life achievements so far.This will go a log way in encouraging african youths to embrace education more seriously.This i assure you will speak louder than all the write ups on you web site.Africa is seriously lagging behind in ICT and a documentary about you transmitted to the would DSTV subscribers in Africa is the magic touch and the greatest thing you

can do to boast education in Africa to encourage your brothers.
You seriously need maximum publicity.You suffered racisim due to the fact the white controlled media outfits used the communication power on you even after you had won all the prizes. But it's still not late.
Hope you are still visiting Nigeria in 2007as you promised. Your are the greatest and don't forget your root - IBO LAND.We have been empowered to bring development to the black world.God has ordained it.

Date:	3/8/2006, 4:55 pm, GMT +6
Name:	Giovanni Foster <200.32.221.152>
Location:	Belize , Central America
Number:	1

This is a must visit site for all people of Afircan decent. I'm an engineering tech.

student @ our local university and i'm tryin to get people familiar wiht this brother.Master Philip Emeagwali's name will be long lived.
Nuff respect to the entire family and to all our prperly governed african states. Ras-pect!

Press CTRL-D to SAVE this page for easy revisit

Press CTRL-P to PRINT