Sir Jagdish Chandra Bose, James Clerk Maxwell and there on…..

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Abstract

IEEE India Council, Bangalore & Bombay sections arranged lectures on Sunday 17th Feb 2019, on the topic "Celebrating Sir Jagdish Chandra Bose"; I had an opportunity to deliver a talk on: Sir. Jagdish Chandra Bose, Maxwell and there on.

There is quite a bit commonality between Acharya Jagdish Chandra Bose and Maxwell. Both of were "Polymath", who influenced the science of that era, in their own way, while their work & theories are quite relevant even today. Due to the efforts of some dedicated Indian Scientists in US, IEEE in 2012 recognized Sir Jagdish Chandra Bose as one of the founding fathers of RF/EM. The talk mostly concentrated on Acharya Jagdish Chandra Bose, his work and impression of his contemporary, workers and friends like Swami Vivekananda, Gurudeo Tagore and his students on his life and work. Similarly, a brief is given on James Clerk Maxwell and his work on various topics with more emphasis on EM equations.

Acharya (Sir) Jagdish Chandra Bose
CSI, CIE, FRS, IPA
(Nov 1858 – Nov 1937)
CSI-Companion of Star of India
CIE-Companion of the Indian Empire
KB-Knight Bachelor

Acharya Jagdish Chandra Bose born on 30 Nov 1858, at Mymen Singh (now in Bangladesh), was an Indian Plant Physiologist & Physicist of great repute. He was a Polymath (Physicist, Biophysicist, Botanist and Archaeologist). He was also a science & science fiction writer in Bengali, in early British India. He is more known for his pioneering investigation of RF & Microwaves (millimeter waves), optics, plant science and first one to lay the foundation of experimental science in the Indian subcontinent. He invented Cresograph, a device for measuring the growth of plant. It is worth mentioning that due to the efforts of some of the Indian scientists, working in US, in 2012 after 127 years of his invention of millimeter waves, IEEE recognized him as one of the founding fathers of RF/EM Engineering. A crater on moon is also named after him. A 1.3mm multibeam receiver, now as the National Radio Astronomy Observatory (US) 12-meter telescope, Arizona, incorporates his original papers of 1897.The Bank of England has decided to redesign the 50 Pounds note with an eminent scientist, Sir J.C Bose has been featured in the nomination.

Perhaps Acharya Jagdish Chandra Bose was never interested in developing communication receiver. He wanted to study the optics like properties of RF waves (at millimeter wavelength). Apparently he was not interested in patenting and publicity otherwise he would have been the inventor of wireless RF communication. In 1896 Marconi met him and gave a proposal for business, which Sir. J.C Bose declined. In the year 1899 Bose announced the development of "Iron-Mercury-Iron coherer with telephone detector". It is believed that his this work influenced the work done by Marconi, Popov and other researchers working on radio communication. Sir. J.C Bose was first to use semiconductor junction to detect radio waves, can be called as father of semiconductor junction diodes. In the year 1897 he presented his work on MMW at Royal Institution in London. He used waveguides, horn antennas, dielectric lenses, various polarizers and even semiconductors at ~60 GHz. We can call him even the father of waveguides and horn antennas.

As per Sir Nevill Mott (Noble Laureate – 1977). Sir J.C Bose was at least 60 years ahead of his time. In fact, Bose anticipated the existence and use of P&N type semiconductors.

As far as education is concerned, he had his graduation from St. Xavier's College Calcutta, Christ's College Cambridge, University College London. He was fortunate to have teachers at Cambridge like Lord Rayleigh, Michael Foster, James Dewar, Francis Darvin, Francis Balfour & Sidney Vines.

Acharya J.C Bose had two famous friends. : Acharya P.C Roy and Gurudeo Rabindranath Tagore. Sister Nivedita, who arranged financial support for his patent, on his coherer invention, in US, also supported him.
Before and besides Sir. Jagdish Chandra Bose and Maxwell, there were many pioneers, who put the formation of electricity, magnetism and electromagnetics: Following is the list of those pioneers.

William Gilbert	1544-1603	Electroscope
Stephen Gray	1627-1691	Electricity
Benjamin Franklin	1706-1727	Static electricity/electricity
Ewald George Von Kleist	1744-	Leyden jar
Charles Augustine de Coulomb	-	Electric charge
Alexander Voltas	1745-1782	Electric cell
Andre Ampere	1775-1786	Electric current
Michael Faraday	1791-1867	Electromotive force Generation of electricity and magnetism Studied the time variation effects on electric and magnetic field
Tesla	1856-1937	Modern A/C system
G.Macaroni	1874-1937	Radio Communication

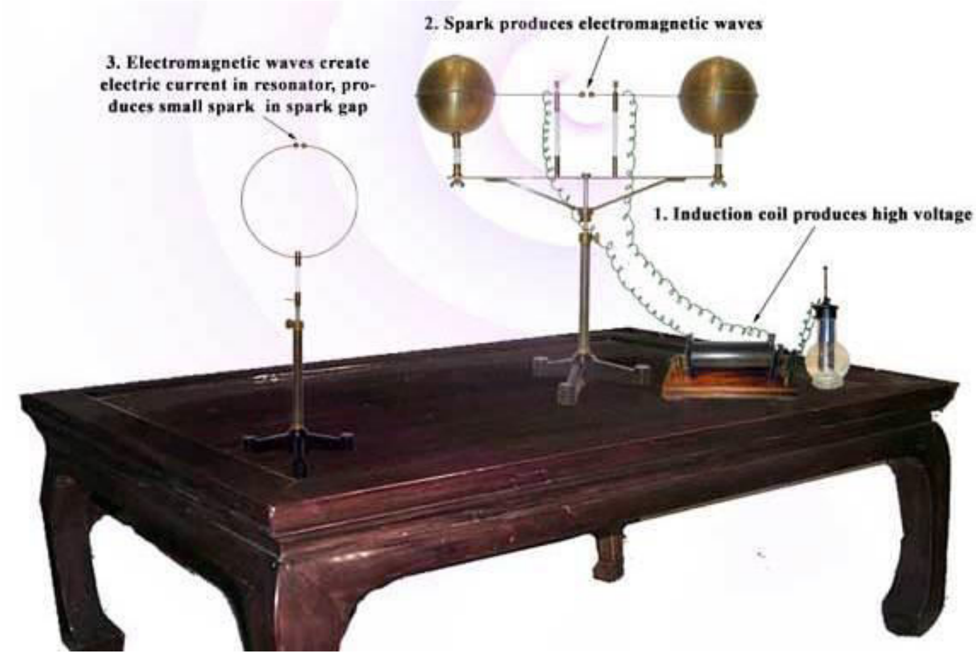
The list is representative and does not include the names of Sir. J.C Bose (1858-1867) & Maxwell (1831-1879), since the talk is about these two great scientists.

RF Wave Experimented demonstration of transmission.

After Theoretical Physicist James Clerk Maxwell who predicted the existence of electromagnetic radiation and work by Heinrich Hertz, Oliver lodge, Acharya Jagdish Chandra Bose in the field of microwave research where he reduced the wavelength to millimeter level (~ 5mm) did most remarkable experimental research. He wanted to study the light like properties of electromagnetic waves like polarization, diffraction, reflection etc which were not possible at long waves. Apparently, he did not use RF for communication purposes.

In 1895 Acharya Jagadish Chandra Bose gave his first demonstration of electromagnetic waves, by ringing a bell remotely across a wall and exploded some gunpowder in the presence of then Lieutenant Governor of Bengal Sir William Mackenzie at Calcutta town hall. He visualized that these invisible rays can pass through a wall and message can be transmitted by using these without using wires. Truly, he was the inventor of wireless communication, though he did not pursue it further.

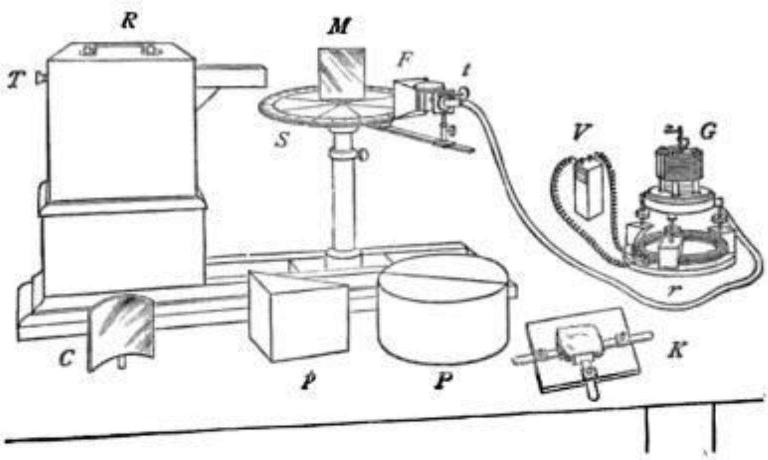
Rudolph Hertz a German Scientist (1857-1894)



Hertz Experiment (1879)

MM Wave Apparatus at JC BOSE Museum Kolkata

Acharya J C Bose with his RF equipment



Line Diagram Of The RF Equipment

In the year 1895 he published a scientific paper "On polarization of electric rays (EM) by double refracting crystals"(Asiatic Society of Bengal). Lord Rayleigh in Oct 1895 communicated Sir Jagdish Chandra Bose's second paper to Royal Society of London. In Dec 1895, London Journal Electrician (Vol 36), published Bose's paper, "On a new electro-polariscope". During the same period, he invented coherer, which he later on patented in US, and was used by G. Marconi to receive signals across Atlantic in Dec 1901. Marconi was celebrated worldwide for his achievement, but the fact that Bose invented the receiver was totally concealed.

Acharya Jagdish Chandra Bose besides working on radio waves (MMW) carried out studies on plants, cell response, metal fatigues.

Sir Jagdish Chandra Bose was a brilliant scientist of his period and his work was appreciated and acknowledged by great scientists of that era like Lord Rayleigh, Lord Kelvin and others. Although in the initial stages he did face some racial discrimination in the British era,in India but his talent was recognized by then Viceroy who supported him to get academic position in Presidency College with full pay enpar with Britishers. I feel Acharya J.C Bose was well recognized by great scientists and even literary figures like Gurudev Rabindranath Tagore.

Acharya J.C. Bose was a great teacher and researcher. Some of his famous students who influenced science in pre and post independence era were:

Prof S.N. Bose, Prof. Meghnath Saha, Prof. Prasad Chandra, Prof. S K Mitra, Prof. Mahalnobis & Prof. D.M. Basu

Acharya Jagdish Chandra Bose and Gurudeo Rabindranath Tagore

Sir Jagdish Chandra Bose had a great admirer and friend in Gurudeo Rabindranath Tagore.*

In 1931, on the occasion of Tagore's Seventieth birthday, Bose confessed, how the Poet had influenced his ideas and his work, opening before him a wider view of life: His friendship has been unfailing through years of my ceaseless efforts during which I gained step by step- a wider and more sympathetic view of continuity of life and its diverse manifestations.

(*Acknowledgement:Biswanth Banerjee Vishva Bharty India)

Tagore found Jagadish Chandra to be endowed with a rare faculty of poetic sensibility and imagination, who appeared to him someone more than a scientist: …" to my mind he appeared to be the poet of the world of facts that waited to be proved by the scientist for their final triumph.. in the prime of my youth I was strongly attracted by the personality of this remarkable man and found his mind sensitively alert in the poetical atmosphere of enjoyment which belonged to me" Hence, to both Tagore and Bose, there never existed any rigid distinction

BOSE and Literature

In his presidential address at the Bengal Literary – Conference in 1911, Bose suggested

"You are aware that, in the West, the prevailing tendency at the moment is, after a period of synthesis, to return upon the excessive sub-division of learning, Such caste-system in scholarship, undoubtedly helps at first, in the gathering and classification of new material. But if followed too exclusively, it ends by limiting the comprehensiveness of truth. The search is endless. Realization evades us. The Eastern aim has been rather the opposite, namely that, in the multiplicity of phenomena, we should never miss their underlying unity. After generations of this quest, the idea of unity comes to us almost spontaneously, and we apprehend no insuperable obstacle in grasping it".

BOSE IN HIS LAST PHASE OF RESEARCH

He pursued in a research to draw a link between the animate and the inanimate in their responses to electric stimulus, and wrote his seminal book, Responses in the Living and Non-living (1902). This project of Bose served to fulfill two crucial purposes: firstly, to contest the Western stereotypical image of India as 'a nation of dreamers', by leaving a distinctly Indian imprint in the corpus of modern science, and secondly, to widen the world view of modern science and to bring a refreshing spirit to the excesses of Western scientific methodology by infusing the Eastern spiritual resources and Vedantic beliefs which proclaim the ideal of the Unity of Life.

Rabindranath Tagore, who had always been an avid supporter of Bose's researches and discoveries, found in his works an essence of Indian scientific spirit, a reflection of Indian national culture, its national pride and heritage. In his poem for Bose, published in Kalpana, Tagore, addressing the scientist, was effusive in praise:

Tagore as a poet on Bose

From the Temple of Science in the West,
Far across the Indus,
Oh, my friend, you have brought
the garland of victory,
decorated the humbled head of the poor Mother ….
Today, the mother has sent blessings
In words of tears,
of this unknown poet.
Amidst the great Scholars of the West
Brother, these words will reach only yours years

BOSE AS A TRUE NATIONALIST

In his letter to Tagore, dated 29th November, 1901, Bose acknowledged his responsibilities as a scientist to revive the national pride of his county: I am alive with the life force of the mother Earth, I have prospered with the help of the love of my countrymen. For ages the sacrificial fire of India's enlightenment has been kept burning, millions of Indians are protecting it with their lives, a small spark of which has reached this country (through me)

Bose's discoveries on electric responses, which were premised alleging the distinctions between the living and the non-living, actually reiterate the ideals of Hindu Vedic Monism that asserts a sense of unity and strength, a grand cosmic unity within the diversity. In this respect, Bose was considerably influenced by Rammohan Roy, who is often designated as the pioneer to rediscover and identify this essential monism within Classical Indian thought, and who according to Bose, was the first to see the "Unity of All Intellectual Life", and the "importance of absolute freedom in all fields of inquiry.

BOSE'S FINAL PHASE OF DISCOVERY

In the final phase of Bose's research could be characterized as the continuation of his endeavor to search for the Unity of Life, in which he attempted to bridge the gulf between the inanimate and the animate worlds by posting the plant world as the progressive connecting link. This phase of Bose's research thus promised to collapse the further existing barriers between different fields of scientific research, thereby strengthening his commitment to his Vedantic belief in cosmic unity.

Acharya JC Bose and Gurudev Rabindranth Tagore

In a tribute to his friend Sir Jagadish Chandra Bose (1858-1937) who died on 23 Nov 1937, Rabindranth Tagore (1861-1941) wrote: Years ago, when Jagadish Chandra, in his militant exuberance of youthfulness, was contemptuously defying all obstacles to the progress of his endeavor, I came into intimate contact with him, and became infected with his vigorous hopefulness. There was every chance of his frightening me away into a respectful distance, making me aware of the airy nothingness of my own imaginings. But to my relief, I found in him a dreamer, and it seemed to me, what surely was a half-truth, that it was more his magical instinct than the probing of his reason which startled out secrets of nature before sudden flashes of his imagination.

James Clerk Maxwell (1831–1879)

James Clerk Maxwell was another Polymath. He is more famous for the theoretical formulation of electromagnetic theory, although he contributed in many areas of Physics.

Maxwell is considered by many physicists to be the nineteenth century scientist with the greatest influence on twentieth century physics. His contributions to the science are considered by many to be of the same magnitude as those of Isaac Newton and Albert Einstein, although he was not as fortunate as the other two in getting laurels and recognition during his life. In 1931, on the centennial of Maxwell's birthday, Einstein himself described Maxwell's work as the: *"most profound and the most fruitful that physics has experienced since the time of Newton"*. Einstein kept a photograph of Maxwell on his study wall, alongside pictures of Michael Faraday and Isaac Newton.

History of Maxwell's equations

Electromagnetism, one of the fundamental fields of physics, the introduction of Maxwell's equations (mainly in *"A Dynamical Theory of the Electromagnetic Field"*) was one of the most important aggregations of empirical facts in the theory of physics. It took place in the nineteenth century, starting from basic experimental observations, and leading the formulations of numerous mathematical equations, notably by Charles-Augustin de Coulomb, Hans Christian Orsted, Carl Friedrich Gauss, Jean Baptiste Biot, Felix Savart, Andre-Marie Ampere and Michael Faraday. The apparently disparate laws and phenomena of electricity and magnetism was integrated by James Clerk Maxwell, who published an early form of the equations, which modify Ampere's circuital law by introducing a ***displacement current term***. He showed that these equations imply that light propagates as electromagnetic waves. ***His laws were formulated by Oliver Heaviside in the more modern and compact vector calculus formalism,*** he independently developed. Increasingly powerful mathematical descriptions of the electromagnetic field were developed, continuing into the twentieth century, enabling the equations to take on simpler forms by advancing mathematics that is more sophisticated.

The concept of electromagnetic radiation originated with Maxwell, and his field equations, based on Michael Faraday's observations of the electric and magnetic lines of force, paved the way ***for Einstein's special theory of relativity, which established the equivalence of mass and energy. Maxwell's ideas also ushered in the other major innovations of 20th century physics, the quantum theory***.

His description of electromagnetic radiations led to the development (according to cassical theory) of the ultimately unsatisfactory law of heat radiation, which prompted Max Planck's formulation of the quantum hypothesis – i.e, the theory that radiant-heat energy is emitted only in finite amounts or quanta. ***<u>The interaction between electromagnetic radiation and matter, integral to Planck's hypothesis, in turn has played a central role in the development of the theory of the structure of atoms and molecules.</u>***

James Clerk Maxwell the Polymath, as a child ad maintained an unquenchable curiosity, for which all came on his way. He developed interest in optics by observing various colours on soap bubbles.

He considered electric & magnetic fields as fluids, wanted to use: **Newton's formula f = ma**

Besides EM theory, he worked on thermodynamics, statistics, atomic movements, RGB (Red, Green & Blue) Colur combination & viscoelastic materials.

Maxwell's equations are a set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electromagnetism, classical optics, and electric circuits. The equations provide a mathematical model for electric, optical, and radio technologies, such as power generation, electric motors, wireless communication, lenses, radar etc. Maxwell's equations describe how electric and magnetic fields are generated by charges, currents, and changes of the fields. One important consequence of the equations is that they demonstrate how fluctuating electric and magnetic fields propagate at the speed of light. Known as electromagnetic radiation, these waves may occur at various wavelengths to produce a spectrum from radio waves to γ-rays. The equations are named after him. He also first used the equations to propose that light is an electromagnetic phenomenon.

$e + \frac{df}{dx} + \frac{dg}{dy} + \frac{dh}{dz} = 0$	(1)	Gauss' Law
$\mu\alpha = \frac{dH}{dy} - \frac{dG}{dz}$ $\mu\beta = \frac{dF}{dz} - \frac{dH}{dx}$ $\mu\gamma = \frac{dG}{dx} - \frac{dF}{dy}$	(2)	Equivalent to Gauss' Law for magnetism
$P = \mu\left(\gamma\frac{dy}{dt} - \beta\frac{dz}{dt}\right) - \frac{dF}{dt} - \frac{d\Psi}{dx}$ $Q = \mu\left(\alpha\frac{dz}{dt} - \gamma\frac{dx}{dt}\right) - \frac{dG}{dt} - \frac{d\Psi}{dy}$ $R = \mu\left(\beta\frac{dx}{dt} - \alpha\frac{dy}{dt}\right) - \frac{dH}{dt} - \frac{d\Psi}{dz}$	(3)	Faraday's Law (with the Lorentz Force and Poisson's Law)
$\frac{d\gamma}{dy} - \frac{d\beta}{dz} = 4\pi p'$ $\quad p' = p + \frac{df}{dt}$ $\frac{d\alpha}{dz} - \frac{d\gamma}{dx} = 4\pi q'$ $\quad q' = q + \frac{dg}{dt}$ $\frac{d\beta}{dx} - \frac{d\alpha}{dy} = 4\pi r'$ $\quad r' = r + \frac{dh}{dt}$	(4)	Ampère-Maxwell Law
$P = -\xi p \quad Q = -\xi q \quad R = -\xi r$		Ohm's Law
$P = kf \quad Q = kg \quad R = kh$		The electric elasticity equation (**E** = **D**/ε)
$\frac{de}{dt} + \frac{dp}{dx} + \frac{dq}{dy} + \frac{dr}{dz} = 0$		Continuity of charge

Maxwell's Original EM equations

Oliver Heaviside (1850-1925

$\nabla \cdot \mathbf{D} = \rho$	(1)	Gauss' Law
$\nabla \cdot \mathbf{B} = 0$	(2)	Gauss' Law for magnetism
$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	(3)	Faraday's Law
$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$	(4)	Ampère-Maxwell Law

Modern Maxwell's Equations (As modified by Oliver Heaviside

The four most common Maxwell relations are the equalities of the second derivatives of each of the four thermodynamic potentials, with respect to their thermal natural variable (temperature T; or entropyS) and their mechanical natural variable (pressure P; or volume V):

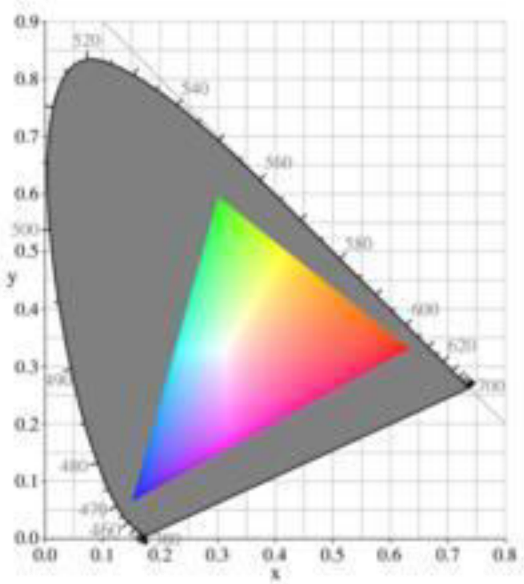
$$
\begin{aligned}
+\left(\frac{\partial T}{\partial V}\right)_S &= -\left(\frac{\partial P}{\partial S}\right)_V = \frac{\partial^2 U}{\partial S \partial V} \\
+\left(\frac{\partial T}{\partial P}\right)_S &= +\left(\frac{\partial V}{\partial S}\right)_P = \frac{\partial^2 H}{\partial S \partial P} \\
+\left(\frac{\partial S}{\partial V}\right)_T &= +\left(\frac{\partial P}{\partial T}\right)_V = -\frac{\partial^2 F}{\partial T \partial V} \\
-\left(\frac{\partial S}{\partial P}\right)_T &= +\left(\frac{\partial V}{\partial T}\right)_P = \frac{\partial^2 G}{\partial T \partial P}
\end{aligned}
$$

where the potentials as functions of their natural thermal and mechanical variables are the internal energy U(S, V), enthalpy H(S, P), Helmholtz free energy F(T, V) and Gibbs free energy G(T, P). The thermodynamic square can be used as a mnemonic to recall and derive these relations. The usefulness of these relations lies in their quantifying entropy changes, which are not directly measurable, in terms of measurable quantities like temperature, volume, and pressure.

Maxwell Boltzmann Distribution

In physics (in particular in statistical mechanics), the Maxwell–Boltzmann distribution is a particular probability distribution named after James Clerk Maxwell and Ludwig Boltzmann

Maxwell's Colour Triangle



The RGB color triangle, shown as a subset of x,y space, a chromaticity space based on CIE 1931 colorimetry

Maxwell Boltzmann distribution in gasses

Maxwell Boltzmann Distribution:In physics (in particular in statistical mechanics), the Maxwell–Boltzmann distribution is a particular probability distribution named after James Clerk Maxwell and Ludwig Boltzmann.

MAXWELL'S THEOREM

In probability theory, Maxwell's theorem, named in honor of James Clerk Maxwell, states that if the probability distribution of a vector-valued random variable $X = (X_1, ..., X_n)^T$ is the same as the distribution of GX for every n×n orthogonal matrix G and the components are independent, then the components $X_1, ..., X_n$ are normally distributedwith expected value 0, all have the same variance, and all are independent. This theorem is one of many characterizations of the normal distribution.Since a multiplication by an orthogonal matrix is a rotation, the theorem says that if the probability distribution of a random vector is unchanged by rotations and if the components are independent, then the components are identically distributed and normally distributed. In other words, the only rotationally invariant probability distributions on R^n that have independent components are multivariate normal distributions with expected value 0 and variance $\sigma^2 I_n$, (where I_n = the n×n identity matrix), for some positive number σ^2.

Maxwell's Materiala

Maxwell material is a viscoelastic material having the properties both of elasticity and viscosity. It is named for James Clerk Maxwell who proposed the model in 1867. It is also known as a Maxwell fluid.

Generalized Maxwell Model:The **Generalized Maxwell model** also known as the **Maxwell–Wiechert model** (after James Clerk Maxwell and E Wiechert[1][2]) is the most general form of the linear model for viscoelasticity. In this model several Maxwell elementsare assembled in parallel. It takes into account that the relaxation does not occur at a single time, but in a set of times. Due to the presence of molecular segments of different lengths, with shorter ones contributing less than longer ones, there is a varying time distribution. The Wiechert model shows this by having as many spring–dashpot Maxwell elements as are necessary to accurately represent the distribution. The figure on the right shows the generalised Wiechert mode

Displacement Current

In electromagnetism, **displacement current density** is the quantity $\partial \boldsymbol{D}/\partial t$ appearing in Maxwell's equations that is defined in terms of the rate of change of $\boldsymbol{D}$, the electric displacement field. Displacement current density has the same units as electric current density, and it is a source of the magnetic field just as actual current is. However it is not an electric current of moving charges, but a time-varying electric field. In physical materials (as opposed to vacuum), there is also a contribution from the slight motion of charges bound in atoms, called dielectric polarization.

The idea was conceived by James Clerk Maxwell in his 1861 paper *On Physical Lines of Force, Part III* in connection with the displacement of electric particles in a dielectric medium. Maxwell added displacement current to the electric current term in Ampère's Circuital Law. In his 1865 paper A Dynamical Theory of the Electromagnetic Field Maxwell used this amended version of Ampère's Circuital Law to derive the electromagnetic wave equation. This derivation is now generally accepted as a historical landmark in physics by virtue of uniting electricity, magnetism and optics into one single unified theory. The displacement current term is now seen as a crucial addition that completed Maxwell's equations and is necessary to explain many phenomena, most particularly the existence of electromagnetic waves.

Maxwell's coil

A **Maxwell coil** is a device for producing a large volume of almost constant (or constant-gradient) magnetic field. It is named in honour of the Scottish physicist James Clerk Maxwell.A Maxwell coil is an improvement of a Helmholtz coil: in operation it provides an even more uniform magnetic field (than a Helmholtz coil), but at the expense of more material and complexity.

Maxwell and light

- Maxwell theoretically showed that EM waves are light waves and vice versa.
- He also calculated the velocity which almost matched with the measured one much after his death.

Maxwell's all calculations were based on observations and empirical formulations which were letter on proved. Hertz was the first to show the generation and propagation of EM waves through spark gap experiment.

The lecture was based on the following open/published literature:

- An appreciation of J.C Bose's pioneering work:. Sarkar T.K & Sengupta D.L (1997) IEEE
- Yogananda Paramhansa (1946) "India's Great Scientist, J.C Bose". Autobiography of a Yogi (1st Edition) New York:
- Bose Institute Website
- Wikipedia (on J.C Bose & Maxwell)
- The Scientist and the Poet: Acharya Jagdish Chandra Bose and Rabindranath Tagore by Biswanath Banerjee-Vishwa Bharati India
- Maxwell's Legacy by James C. Rautio IEEE-Microwave Magazine-June 2005
- Encyclopedia Biography of World Great Scientists
- History of Wireless Communication-Microwave Journal 2015.

About the author

Dr.Surendra Pal is a space communication, RF, EM and GNSS expert. He is currently Dr. D.S.Kothari DRDO Chair. He was the Vice Chancellor of Defence Institute of Advanced Technology (DIAT), Pune, Prof. Satish Dhawan Professor, Senior Adviser and Programme Director of Satellite Navigation, ISRO, Bengaluru. He was also the Distinguished Scientist, Associate Director and Chairperson of GAGAN-PMB. He is a Fellow of IEEE, Fellow of Indian National Academy of Engineers (FNAE), Fellow of National Academy of Science (FNASc), Distinguished Fellow of IETE and Fellow of the IET. He had served as the national President of IETE during 2012-12.