BEYOND ELECTRICITY AND MAGNETISM: MAKING SPACE AND TIME PLAY NICE WITH MATTER AND FORCES

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ABSTRACT

I present a few special topics in the modern application of E+M. I then explain the twin revolutions that happened in ~1905 due to our understanding of light from Maxwell's Equations. I then discuss modern efforts to see if these twins can learn to play nice with one another.



NASA Concept Art for Variable Specific Impulse Magnetoplasma Rocket (VASIMR).

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BIOELECTRICITY

Ampullae of Lorenzini



Threshold of sensation: 5nV/cm

Electric eels (and other animals) have special cells called "electrocytes". They are pancake shaped, with opposite charges on opposite sides, each generating 0.15V. Thousands of these act together to create high-voltage and low-voltage electrical discharges



Live frog levitating in a 10 Tesla magnetic field.

TWIN REVOLUTIONS (CA 1900)

THE DAWN OF A CENTURY



Mechanics described the universe as a perfect clockwork machine whose outcomes could be exactly predicted at all scales.



Thermodynamics described heat and its relationship to work and energy



Electromagnetism explained all electrical and magnetic phenomena, predicted new ones, and explained light as a wave.

ANNOYING LITTLE PROBLEMS

- There were just some "annoying little problems" left to explain away:
 - Maxwell's Equations claimed no medium was needed for light to propagate, yet all other waves required a medium.
 - if light is a wave, it needs a medium "the aether"
 to progagate. We just had to find it!
 - extremely sensitive experiments failed to discover any such medium.

ANNOYING LITTLE PROBLEMS

- There were just some "annoying little problems" left to explain away:
 - Maxwell's Equations also had a problem with "motion"
 - "The Galilean transformation" related experiments conducted by moving observers and those conducted by stationary observed.
 - Applying the transformation to Maxwell's Equations led to conflicting predictions about what a moving and stationary observer each predict is going on in the other person's frame of reference.

The problem of the aether and the problem of motion led most physicists to conclude that the newly uncovered "Maxwell's Equations" were wrong. After all, how could classical physics uncovered over 200 years be wrong?

ANNOYING LITTLE PROBLEMS

- There were just some "annoying little problems" left to explain away:
 - Thermodynamics: a body that absorbed radiation and released it as heat - a blackbody - was predicted to emit high frequency/short wavelength light with increasingly higher and higher probability

- "the ultraviolet catastrophe"

THE LILTRAVIOLET CATASTROPHE

MAX PLANCK 1858-1947



German physicist

Made central contributions to the study of heat (thermodynamics).

Turned his attention to the problem of blackbody radiation in 1894, motivated simply by wanting to understand this phenomenon.

By 1901, he had reluctantly published an explanation based on two principles: statistics and electromagnetic energy quantization the idea that a light wave cannot have any energy that it wants.

"AN ACT OF DESPERATION" "... a theoretical interpretation Lof the blackbody spectrum] had to be found at any cost, no matter how high." (Max Planck, in a letter to R.W. Wood)

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ELECTROMAGNETIC ENERGY QUANTIZATION

E = h f

The frequency of electromagnetic radiation (light)

Electromagnetic ENERGY

A new constant -"Planck's Constant"

 $h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$





Albert Einstein (1879-1955)

Fascinated by magnetism as a very early age (his father ran a company that manufactured direct current electrical equipment). Showed early talent for engineering and mathematics.

Attended the Swiss Federal Institute of Technology (ETH) in Zurich in 1896 for a teaching diploma; he had shown outstanding performance in mathematics and physics on an earlier entrance exam.



Albert Einstein (1879-1955)

Met his first wife, Mileva, at ETH (she was the only woman in a class of 6 that entered the teaching diploma course in 1896). They were married in 1903. She failed the exam for her teaching diploma, while Einstein passed the exam.

After two frustrating years searching for a teaching post, Albert got a job at the Swiss Patent office (helped by his friends) in 1900. He worked on patent review for electromagnetic devices.



Albert Einstein (1879-1955)

Einstein continued to work toward a Ph.D., which was awarded in 1905. That same year, he published four groundbreaking papers. These papers concerned:

- the atomic theory of matter
- how motion affects measurement (relativity)
- the nature of light
- the equivalence of matter and energy



Albert Einstein (1879-1955)

Einstein's most seminal work was published in 1919:

- the general theory of relativity
 - beautifully united space and time into a single, four-dimensional system ("spacetime")
 - gravity is explained by geometry
 - matter and energy tell
 spacetime how to warp (bend)
 - spacetime's warping tells matter and energy how to move

RELATIVITY AND QUANTUM PHYSICS

EINSTEIN'S LEGACY

- Light can be treated as BOTH a particle and a wave (quantum theory of radiation)
 - depends on the wavelength and how it compares to the dimensions of the target (e.g. atoms)
- . What's so special about light? (quantum theory of matter)
 - if light can be BOTH a particle and a wave, is matter also actually a wave too?
 - matter (electrons, protons, etc.) was confirmed to have wave properties (confirmed in 1927 at Bell Laboratories)
- . No definite state, only definite possibilities
 - if all things radiation and matter are waves, they they do not possess definite properties (e.g. an electron cannot be said, with absolute certainty, to be in one place and not another)
 - . Probability, describing DEFINITE POSSIBILITIES, rules.

EINSTEIN'S LEGACY

- Space and time are not fixed (relativity)
 - different observers AGREE on events, but not where or when they happen
 - All observers measure the same speed for light, REGARDLESS of their state of motion
- Energy and mass are the same thing (relativity)
 - light is pure kinetic energy (no mass)
 - nothing can travel faster than light in vacuum
 - mass can be turned into pure energy, and pure energy into mass

A Wrinkle in Space-Time

Putting Einstein to the Test

Gravity Probe B is to gauge the subtle twisting and warping effects of the Earth on surrounding space and time.



This micrograph, which represents the surface of a gold specimen, was taken with a sophisticated atomic force microscope (AFM). Individual atoms for this (111) crystallographic surface plane are resolved. Also note the dimensional scale (in the nanometer range) below the micrograph. (Image courtesy of Dr. Michael Green, TopoMetrix Corporation.)





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MAKING GENERAL RELATIVITY AND QUANTUM PHYSICS PLAY NICE





"String Theory" (now known by a more appropriate and general term - "M-Theory") is one attempt to reconcile general relativity and quantum physics.

Fundamentally, M-Theory is all about geometry, and how higher-dimensional objects behave and how their dynamics leads to what we observe in spacetime.



A two-dimensional projection of a 7-dimensional "Calabi-Yau Manifold" - one way that extra dimensions may compactify and avoid detection in everyday life.

A Black Hole - a collapsed star remnant so compact it warps spacetime so strongly not even light can escape



March 7, 2005 Kresge Auditorium + 4:00 p.m NOBI PREATE LECTURE SERIES The Universe a Strange Place ank Wilczek 2004 Nobel Laureate in Physics

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OUR PLACE IN THE COSMOS

WHAT WE KNOW TODAY

. The universe is VERY OLD

- . 13.7 ± 0.13 Billion Years
 - _ we know this most precisely by studying the cosmic microwave background (light from the big bang)
 - _ Everything in the universe appears to be moving apart
 - _ we can make estimates of the minimum age by studying the distance of stars from earth, using optics (parallax) and the known speed of light.

. The earth is VERY OLD

- . the earth formed 4.5 Billion Years ago
 - we know this by measuring the radioactivity of very old rocks, among other things
- . The universe is mostly NOT understood
 - . 96% of the universe's composition is unknown
 - . 15 years ago, nobody would have believed this statement

THE BIG DIPPER



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FINAL WORDS

- Be humble before the cosmos
 - Asking the universe questions means making assumptions you can test, and knowing how to test them
 - Listen to the universe, and do not be afraid of what it has to tell you
- Question with courage and wisdom
 - . Have the temerity to question
 - Have the wisdom to learn how to answer those questions
 - apply what you learn and create new knowledge

MORE INFORMATION

SHAMELESS PROPAGANDA

- Good reads
 - "The Elegant Universe" (Brian Greene)
 - "The 4% Universe" (Richard Panek)
 - "The Very First Light" (John Mather and John Boslough)
- Good listens
 - Science Hour with Dr. Kiki (twit.tv)
 - Mustang Physics (SMU Physics Podcast) http://blog.smu.edu/mustangphysics