Chapter-1 Relativity Part I <u>RADIATION</u>

- Radiation implies the transfer of *energy* from one place to another.
 - Electromagnetic Radiation Light
 - Particle and Cosmic Radiation photons, protons, neutrons, electrons pions, etc.
 - Solar Radiation ionized electrons- plasma
 - Thermal Radiation Infrared
 - Ultraviolet Radiation -
 - Ultrasonic Radiation Ultrasound >50KHz
- Maxwell showed that the electromagnetic radiation (EM) can be explained by a *plane* wave



• Energy transfer is given by the Poynting Vector $S = 1/\mu o E \times B (W/m^2)$ W/m² \rightarrow (Energy/time)/area

DIPOLE ANTENNA

Consider a dipole antenna emitting EM radiation. The E-field follows the charge up and down, The B-field circulates about the current I flow up and down.



<u>SPEED OF LIGHT</u>

- EM Radiation travels with the speed of light $c = 3.0 \times 10^8 \text{ m/s}$
- Galileo believed the speed of light to be finite and attempted to measure it in the 17th century but did not succeed.





• The speed of light was measured by Danish astronomer Ole Roemer in 1670 by using Jupiter's moon Io. Io makes one complete orbit around Jupiter every 1.76 days;



As Jupiter moves away from earth in its orbit, Roemer predicted the arrival time of the new moon would be delayed by the time it took the light to travel the extra distance. He was right! $v_{\text{LIGHT}} \approx 300,000 \text{ km/s}$

• Most scientist believed that light needed a medium to propagate.

- In 1856 Maxwell's equations represent one of the most elegant and concise ways to state the fundamentals of electricity and magnetism. He assumes the speed of light *c* to be **constant.**
- In 1888 Heinrich Hertz measured the speed of electromagnetic waves produced in his laboratory to be about 300,000 km/s strongly implying the light and electromagnetic waves are the same thing!

Maxwell's Equations

Integral form in the absence of magnetic or polarizable media:

Hertz Dipole Antenna Waves



- Top scientist believe we are traveling through an *ether* and the speed of light must be affected! This is inconsistent with Maxwell's theory.
- "The Laws of motions were the same throughout the universe", why not the laws of Electromagnetism??
- Does light needed a medium to travel in ?? Don't all waves need a medium to travel ??

ETHER HYPOTHESIS

• Our relative motion to the ether must be considered.





Earth moves through a stationary Ether?
Stars are fixed in place relative to this motion.
Copernicon View.
Aberration of Starlight- Telescope tilt dependent on velocity through the either!
ABERRATION OBSERVED
tanθ = V_E/c = 9.9 x 10⁻⁵ rdn

Earth drags the Ether along?
The earth is a special nonCopernicon frame.
No Abstration of Starlight telescope

•No Aberration of Starlight - telescope tilt independent of the Earth's velocity.

ETHER FLOW



- The river (ether) flows at speed V.
- The time for round trip-1 across the river includes extra time to "buck the current".
- The time fot trip-2 with and against the flow includes less time and then more time respectively. (see page 8-9)

 $\begin{aligned} \Delta t &= t1 - t2 = (2L/c) / (1 - V^2/c^2)^{1/2} - (2L/c) / (1 - V^2/c^2) \\ &= (2L/c) / \{ (1 + 1/2 V^2/c^2 + ...) - (1 + V^2/c^2 + ...) \} = (2L/c) \{ 1/2 V^2/c^2 + ... \} \\ \Delta t &= LV^2/c^3 + ... \end{aligned}$

• Light would take a small but different time to make trip-1 as compared to trip-2!



LORENTZ- FITZGERALD CONTRACTION

• In a "last ditch effort" Lorentz and Fitzerald propose that the apparatus has shrunk L->L/ γ due to the ether by just the factor needed to "save the ether". But not well accepted.

$$\beta = V/c \qquad Relative speed \qquad 0 \rightarrow 1$$

$$\gamma = (1 - \beta^2)^{-1/2} \qquad Lorentz \ factor \qquad 1 \rightarrow \infty$$

Interference Pattern or not?

EINSTEIN'S POSTULATES OF RELATIVITY

- **The Principle of Relativity-** All physical laws have the same form in all inertial reference (non-accelerating) frames.
 - -Electricity and Magnetism and Mechanics on the same footing.
- The Consistency of the Speed of Light- The speed of light *c* in the same in all inertial reference frames. How can this be??



- Einstein proposes a picture of 4-dimensional spacetime- $(x \ y \ z \ t)$ in which c = constant !
- Newton's Laws are shattered.
- Maxwell's Electromagnetic Theory survives.

LENGTH CONTRACTION

<mark>ΔL= ΔL_o/γ</mark>

Observers traveling with relative speed $\beta = V/c$ will measure the length of a ruler in each others frame as being shorter than the length measured length when both at rest -> *Proper Length Lo.*



TIME DILATION

 $\Delta t = \gamma \Delta t_o$

Observers traveling with relative speed $\beta = V/c$ will measure shorter time intervals in each others reference frame as compared to the time interval measure when both are at rest->*Proper Time* Δto .



RELATIVISTIC DOPPLER SHIFT

Consider light of frequency *fo* being emitted from a source. An outside Observer will measure a shifted frequency coming from the source

$$f = fo_{\sqrt{\frac{1-\beta}{1+\beta}}}$$

Source moving away from the Observer with relative speed β . RED SHIFT

$$f = fo_{\sqrt{\frac{1+\beta}{1-\beta}}}$$

Source moving toward the Observer with relative speed β . BLUE SHIFT

 $\lambda = f / c$



LORENTZ TRANSFORMATION

Einstein used the Lorentz transformation to form a 4-dimensional spacetime.

Let x' t' denote the position and time in the laboratory system Let x t denote the position and time in the moving system.

Lorentz Transform	Derivative	
$x' = \gamma (x + vt)$	$dx' = \gamma (dx + v dt)$	
$t' = \gamma (t + v x/c^2)$	$dt' = \gamma (dt + v dx/c^2)$	



Velocity Transform

$$Vx' = dx'/dt' = (dx + \beta cdt) / (cdt + \beta dx)$$

$$Vx' = \frac{Vx + v}{1 + Vx \bullet v/c^2}$$

v= relative velocity

Vx = velocity of an object in the moving frame.

Vx' = velocity of the same object as measured in the Lab frame.

$V_X \ll c \rightarrow$	$V_X' = V_X + v$	NEWTON
$Vx = c$ (flashlight) \rightarrow	Vx' = c	EINSTEIN



