

1. Announcements

Announcements

- Homework 1 due today
 - Hand in at end of class
- Homework 2 is posted
- Recitations today & Thursday
- Office hours today 3:00-4:00
- Groups should be organized & working

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2. Galilean relativity (cont’d)

Galilean relativity (cont'd)

- Acceleration same in either Frame of Reference - none in x-direction & -g in y-direction
- So $\mathbf{F} = m\mathbf{a} = m\mathbf{a}'$
Newton's 2nd Law unchanged
- There is no way to determine which Frame of Reference is "at rest" by doing experiments!
- How do you feel in uniformly moving train or plane?
- What about waves in moving water? Or planes flying through air current? Or boat in current? Or sound waves in air?
- There is a medium and a preferred or absolute frame for these waves.

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3. Laws of Physics are Invariant

Laws of Physics are Invariant

- Newton's 2nd Law is unchanged in all **inertial** frames
- What about light - EM waves?
- Maxwell's waves - Review



J.C. Maxwell



Isaac Newton

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4. Electromagnetic waves

Electromagnetic waves

- T. Young (1801) showed that light behaves like a wave - it undergoes **interference**
- Mechanical waves - water, sound, vibrating strings and solids - are **disturbances** of a **medium** that **propagate** due to **elasticity** of the medium
- If light is a wave, what is waving?
- Maxwell (~1860) theorized that light is an EM wave (prediction from unifying E&M)

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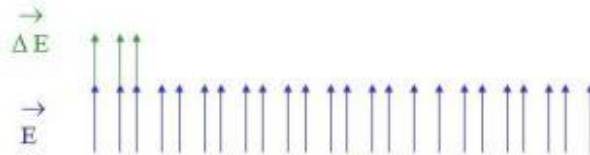
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5. Lecture 4: EM Waves, Ether, Light: Slide 5

Lecture 3 - EM field - wave 1



E field is stationary in some inertial frame **S**
e.g. at a distance from large fixed charge

See *External Links* for animated [EM wave](http://www.phy.ntnu.edu.tw/ntnujava/viewtopic.php?t=52)
(<http://www.phy.ntnu.edu.tw/ntnujava/viewtopic.php?t=52>)

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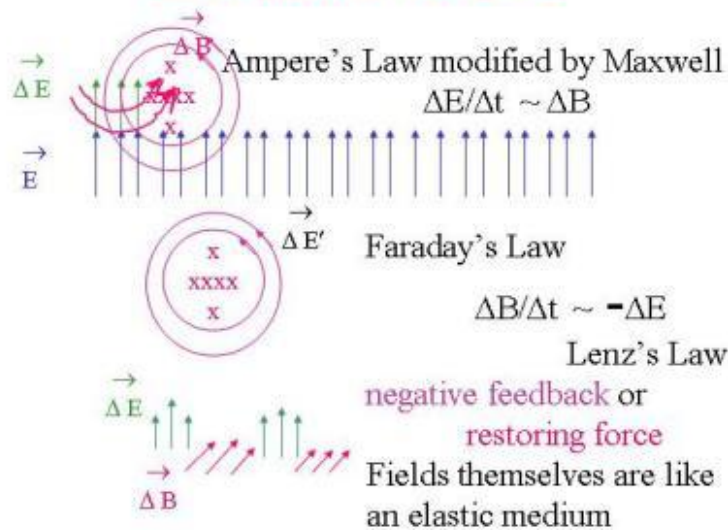
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6. Lecture 4: EM Waves, Ether, Light: Slide 6

EM field wave 2



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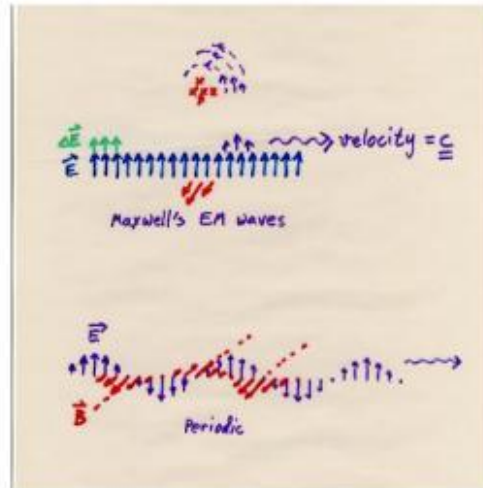
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7. EM field wave

EM field wave



c depends on “restoring force” and “inertia” of stationary fields

E (electric force field) and B (magnetic force field) are perpendicular

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8. Maxwell EM waves

Maxwell EM waves

- Initial field (or vacuum ?) is stationary in some frame which has some “ponderable” properties
- Frame in which ether is at rest is an absolute reference
- Motion through ether should cause change in speed of wave

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9. Light swimming

Light swimming

- Consider earth “swimming” through ether
- Ether is the medium for light waves that permeates all space
- Ether is at rest (relative to “fixed stars”)
- Light parallel to earth’s motion should be slower making a round trip than light perpendicular

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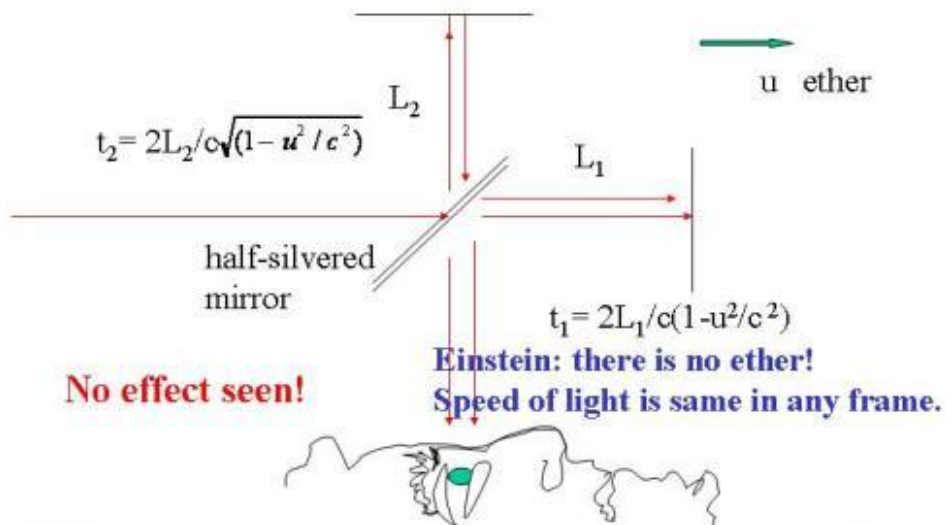
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10. Michelson-Morley Experiment(1887)

Michelson-Morley Experiment(1887)



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11. Transporting time & clocks

Transporting time & clocks

- Train schedules - departure & arrival times
- How can clocks be synchronized? (Patents)
- Carry clock on train to all stations
- What if train clock isn't in synch with first station?
- Send out signals - sound (whistles), cables (telegraph), radio or light waves

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12. Railroad clocks

Railroad clocks



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13. All phenomena

All phenomena must be described by setting up coordinate systems or frames of reference

Like a grid with clocks

Station platform

Clocks synchronized by light signals throughout space

Spatial grid set up by light beams & right angles

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14. Synchronizing clocks

Synchronizing clocks

- Clock 1 at $(x,y,z)=(0,0,0)$ reads $t_1=0$ when it sends a signal to Clock 2 at $(d,0,0)$.
- Clock 2 receives signal at $t_2=d/c$. So it must be set to read $t_2=d/c$ at that moment (not 0).
- When Clock 2 reads t_2 it sends a signal to Clock 3 at $(2d,0,0)$. Latter gets signal at t_2+d/c and is set to display that value.
- Similar procedure is followed for the whole frame.

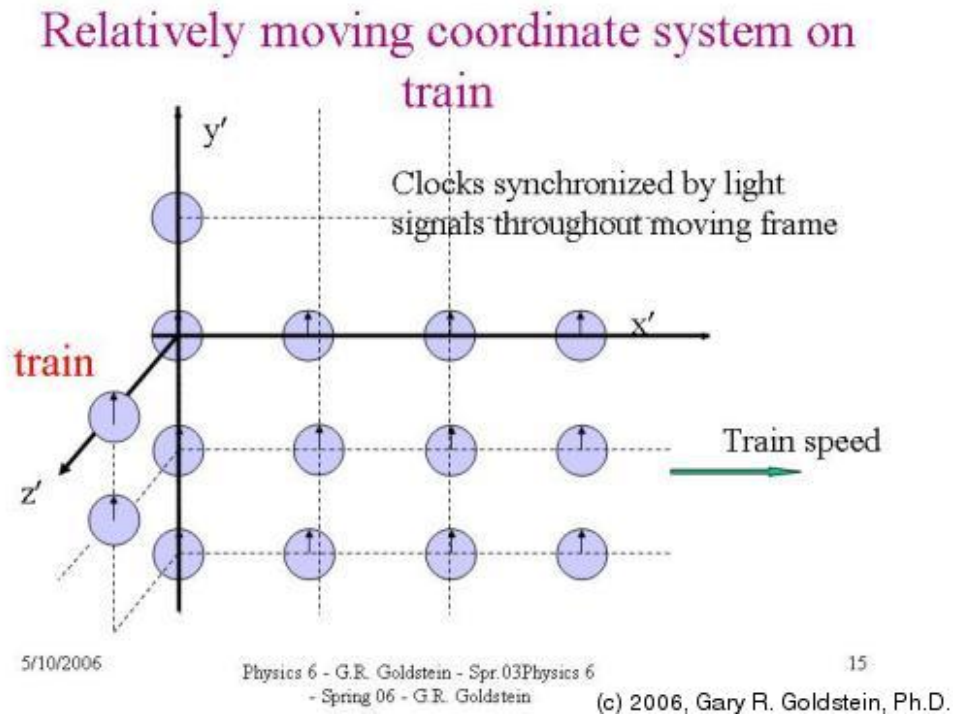
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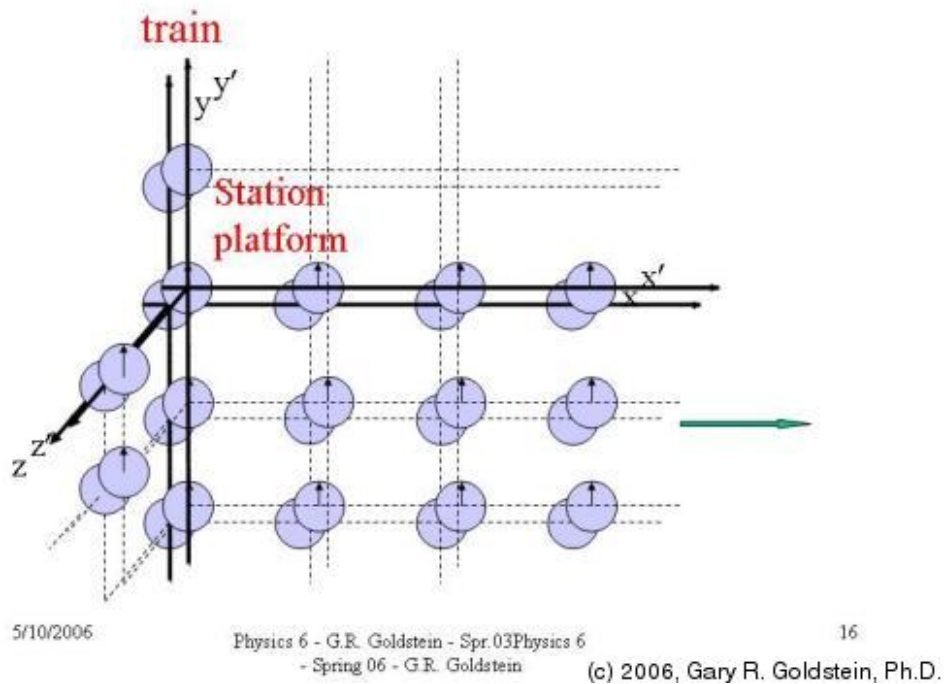
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15. Lecture 4: EM Waves, Ether, Light: Slide 15



16. Lecture 4: EM Waves, Ether, Light: Slide 16



17.

Special Relativity

Special Relativity

- Einstein (1905 Miraculous Year!) required
 - Laws of Physics are independent of inertial frame *or* one can not detect absolute motion
Think about being on a moving train.
 - Speed of light (**c**) is independent of the motion of the source *or* c is velocity of EM wave in any inertial frame
($c=300,000,000$ m/s or 186,000 miles per second)
Think about ultimate speed. Also no ether.
- 2 innocent requirements. Can these be compatible?
 - Construct a light clock

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