2 of you not in BlackBoard yet
- Need to get that fixed.

Probs sets outside B+L 203E

[Diagram with labels: Quad, main lobby, B+L, Promised land, your papers]
Last Time

Speed of light constant (same)
for all observers

Physics invariant

Observer on truck

Observer on ground

Speed of light invariant
Distance light travels depends on point of view

⇒ light travel times differ ⇒ Time is relative

Across all inertial frames of reference

Non-accelerating
\[ T_{\text{ground}} = T_{\text{truck}} \sqrt{\frac{1}{1 - \left(\frac{v}{c}\right)^2}} \]

One special frame of reference
\[ \rightarrow \text{event happens at rest} \]
(Truck frame)

In proper frame \[ \rightarrow \text{Time is shortest} \]
other frames Time "dilates"
\[ t = \gamma t' \]

Diagram showing coordinate systems with labels and notes: "at rest in S'".
Length contraction

(only in direction of relative motion)

\[ \Delta x = \frac{\Delta x'}{\gamma} \]
\[ \gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} \approx 5 \]

How long is the football field to observer in spacecraft?

\[ \left( \text{Football field length}_{\text{space ship}} \right) = \frac{100 \text{ yds}}{\gamma} \]

\[ = 20 \text{ yds} \]
What does it mean for two events to be simultaneous?

See last few pages of relativity slides → Lorentz transformations
unlike poles attract… say that one bar magnet creates a condition in space called a “magnetic field” that causes force on the other bar magnet.
We saw this with demo

Moving electric charge creates a magnetic field

Also magnetic field causes force on moving charged particles

Saw this in demo with current-carrying wire in strong magnetic field
Demonstration of current in two wires

Wires are attracted to each other (repelled if current in two wires in different directions)

→ Due to magnetic field

Charges viewed at rest

Force thought to be due to electric field
view same thing while running past charges very fast

\[ \text{Now charges look like currents!} \]

\[ \text{force attractive and thought to be due to magnetic field!} \]

All that changes is the point of view of observer

So there's a deep relationship between electric and magnetic fields. Einstein saw this. Special relativity shows how electric + magnetic fields get "mixed up" by Lorentz transformations \ldots a bit like what happens in space + time \ldots (slightly more complex)
Before Einstein it had been shown that electric and magnetic fields are different faces of the same force.

Maxwell's Equations

James Clerk Maxwell

1831-1879 (Edinburgh)

"E" is symbol for electric field

"B" is symbol for magnetic field

\[ \oint_S \vec{E} \cdot d\vec{a} = \frac{Q_{encl}}{\varepsilon_0} \]

\[ \oint_S \vec{B} \cdot d\vec{a} = 0 \]

\[ \int_c \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \oint_S \vec{B} \cdot d\vec{a} \]

\[ \int_c \vec{B} \cdot d\vec{l} = \mu_0 I_{encl} + \mu_0 \varepsilon_0 \frac{d}{dt} \oint_S \vec{E} \cdot d\vec{a} \]
E, B are "unified" in one framework. Deeper relationship understood by Einstein.

Maxwell unified Electric \( \rightarrow \) forces

Magnetic

into Electromagnetism

Induce

Changing electric field

Induces

Changing magnetic field

Induces

Changing electric field

Propagates out at speed of light!
Fist full of Electric charge \( \rightarrow \) creates changing \( E \) which induces changing \( B \) which induces changing \( E \) \( \rightarrow \) Propagates outward at speed of light \( \rightarrow \) it is light

Maxwell's equa. also tell us that \( E, B \) satisfy wave equations

Waves are a well-known mechanical phenomenon

\[ \rightarrow \text{ Wave pulse traveling on a string} \]
\[ v = \frac{\lambda}{T} \]

Waves:

- Wave equation:
  - \( y = \sin(\omega t) \)
  - \( \omega = \frac{2\pi}{\lambda} \)
  - \( v = \frac{\lambda}{T} \)

- Amplitude:
  - \( A = \frac{y_{peak}}{y_{avg}} \)

- Velocity:
  - \( v = \frac{\lambda}{T} \)
  - \( \lambda \) is the wavelength
  - \( T \) is the period
Frequency, \( f \) \( \equiv \frac{1}{T} \) (s\(^{-1}\))

\[ v = \lambda \nu \]

\[ v = c f \]

Light, Sound, miles