"Physical conceptions are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world."

-- Einstein

1

Last Time

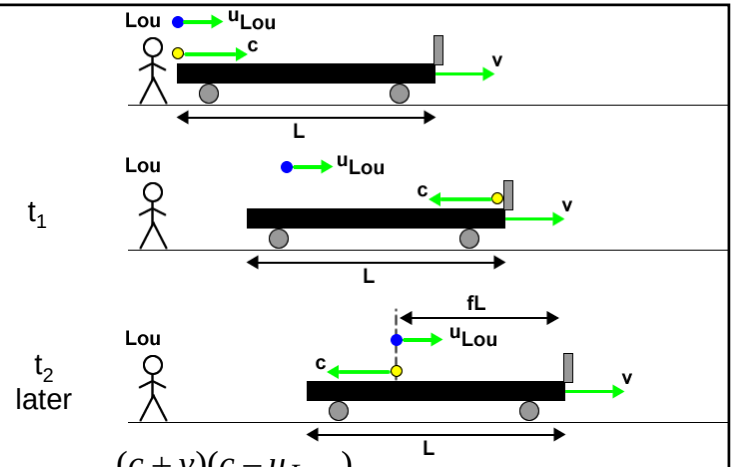
- Relativistic Doppler Effect
- Length Contraction
- Simultaneity
- The Interval
- Spacetime Diagrams
- The Dimensions of Spacetime

2

Today

- Addition of Velocities
- Relativistic Momentum
- Relativistic Energy
  - $E = m c^2$

3



$$f = \frac{(c+v)(c-u_{Lou})}{(c-v)(c+u_{Lou})}$$

4

Recall (Jan 5, Mar 16): You pursue a sound wave at 99% of the speed of sound relative to the air

You will observe:

A. A sound wave moving away from you at the speed of sound

B. A sound wave moving away from you at about 1% of the speed of sound

C. A stationary sound wave

D. You can not pursue a sound wave at 99% of the speed of sound

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Another Chain of Reasoning

Einstein: the speed of light is the same for all observers

THEREFORE

Velocities do not add according to our common sense

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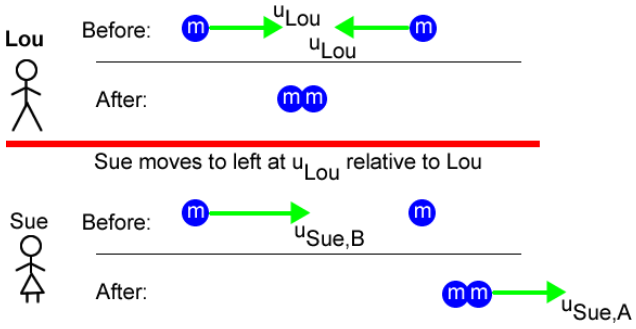
Inelastic Collisions



$u_{Sue,A}$ is:

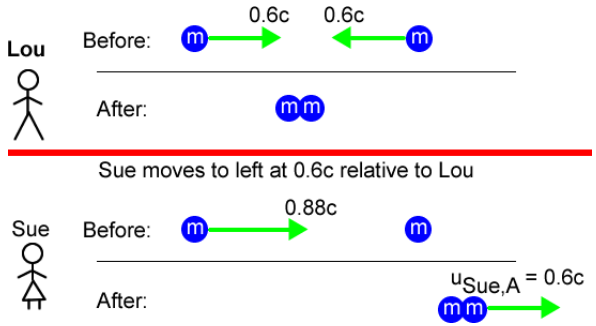
A. $< u_{Lou}$

B. $= u_{Lou}$

C. $> u_{Lou}$

7

Some Numbers



According to Newtonian Conservation of Momentum, $u_{Sue,A}$ is:

A. 0

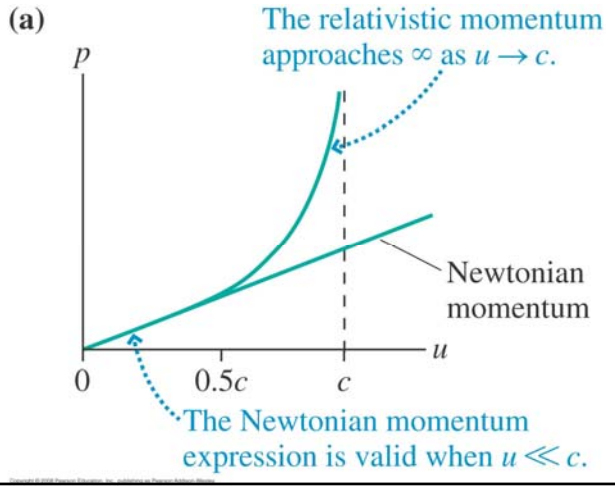
B. 0.44c

C. 0.6c

D. c

8

Figure 37.34 (a)



9

Recall March 23: You pursue a light wave at 99% of the speed of light relative to the source of the light wave

You will observe:

A. A light wave moving away from you at the speed of light
B. A light wave moving away from you at about 1% of the speed of light
C. A stationary light wave
D. You can not pursue a light wave at 99% of the speed of light

10

Einstein (age 16): If you pursue a beam of light at the speed of light relative to the source of the light beam you will see:

A. The beam of light moving away from you at the speed of light.
B. A beam of light moving away from you at 1% of the speed of light.
C. A stationary light wave.
D. You can not pursue a beam of light at the speed of light.

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Another Chain of Reasoning

Einstein: the speed of light is the same for all observers

THEREFORE

Velocities do not add according to our common sense

THEREFORE

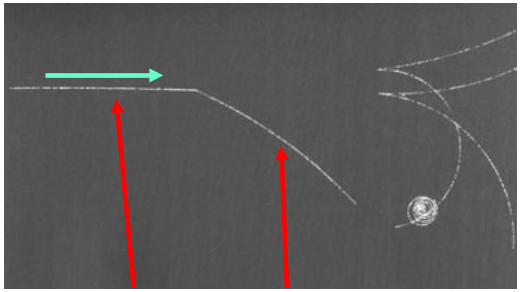
If momentum is conserved it must be

$$\vec{p} = \frac{1}{\sqrt{1-u^2/c^2}} m\vec{u}$$

12

Bubble Chamber

Charged particles leave tracks
Magnetic field into the screen
curves the tracks



$K^- \Rightarrow \pi^- + \pi^0$

$\pi^0 \Rightarrow$ 2 photons

Each photon => electron-positron pair 13