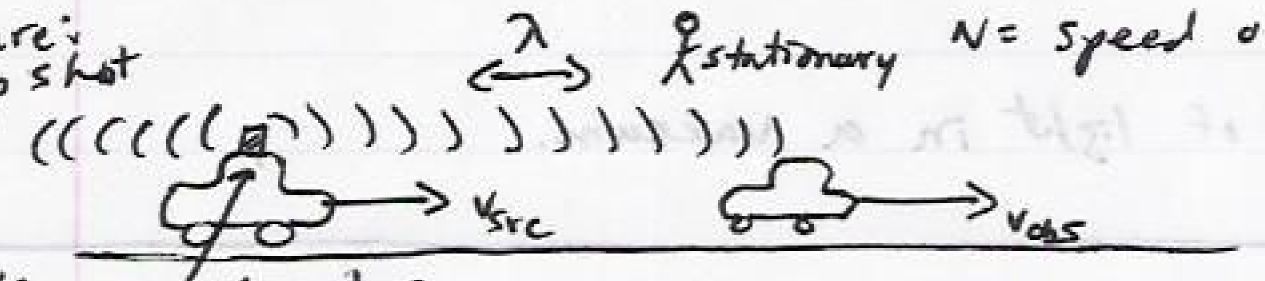
11-10-10

Today: Ch. 36 (Special Relativity)

Doppler effect for sound waves.

Picture: snap shot



v = speed of sound

$\frac{\text{cycle}}{\text{time}} = f_{src} = \frac{1}{T_{src}} = \frac{1}{\text{time/cycle}}$ Source

observer

$$\underset{\text{of wave}}{\text{Speed}} = \frac{\text{distance}}{\text{time}} = \frac{\text{distance/cycle}}{\text{time/cycle}} = \frac{\text{wavelength}}{\text{period}}$$

From source's point of view, sound is moving forward at speed $v - v_{src}$.

$$v - v_{src} = \frac{\lambda}{T_{src}} = \lambda f_{src}$$

(In the middle from a stationary person's point of view, $v = \frac{\lambda}{T_{mid}}$)

From front cars point of view, $v - v_{obs} = \frac{\lambda}{T_{obs}} = \lambda f_{obs}$

$f_{obs} = \frac{1}{T_{obs}} \longrightarrow T_{obs} = \frac{1}{f_{obs}} \longrightarrow \underbrace{(v - v_{obs})T_{obs} = (v - v_{src})T_{src} = vT_{mid}}_{\text{Sound waves}}$

$$\Rightarrow \left\{ \begin{array}{l} \lambda = \frac{v - v_{obs}}{f_{obs}} \\ \lambda = \frac{v - v_{src}}{f_{src}} \\ \lambda = \frac{v}{f_{mid}} \end{array} \right\} \Rightarrow \boxed{\frac{v - v_{obs}}{f_{obs}} = \frac{v - v_{src}}{f_{src}}} = \frac{v}{f_{mid}} \longrightarrow \boxed{f_{obs} = \left(\frac{v - v_{obs}}{v - v_{src}}\right) f_{src}}$$

Doppler Effect for sound

Doppler Effect for EM waves

$$f_{obs} = \sqrt{\frac{v - v_{obs}}{v - v_{src}}}\, f_{src}$$

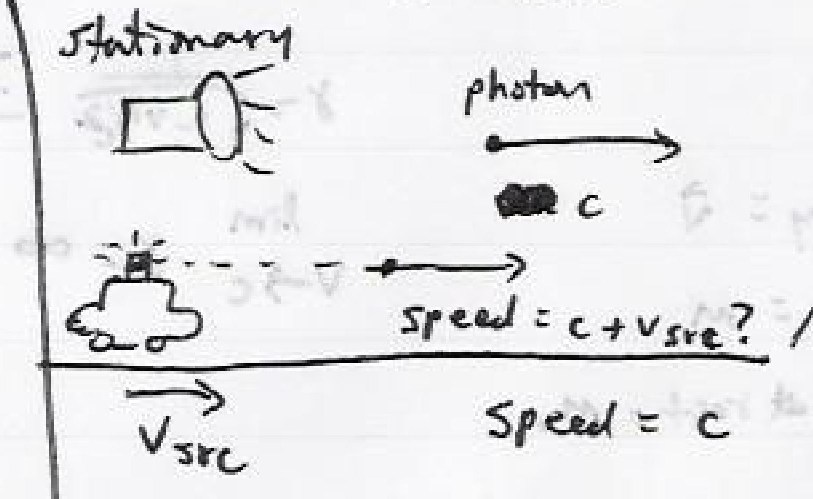
$\uparrow$

v = speed of light = $\frac{c}{n}$

c = speed in vaccum = $\frac{1}{\sqrt{\epsilon_0 \mu_0}}$

n = index of refraction

In a vaccum



speed = $c + v_{src}$? No

Speed = c

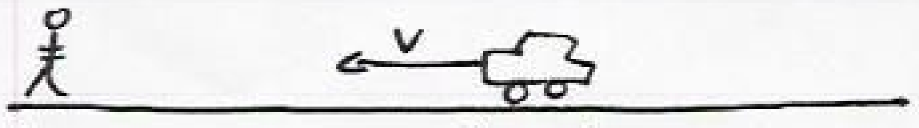
Einstein's Postulate (hypothesis/assumptions)

① All observers' measurements match the same laws of physics; i.e., the laws of physics are the same for everybody.

(2) All observers measure the same speed of light in a vaccum.

Consequences of (1) + (2):

length contraction

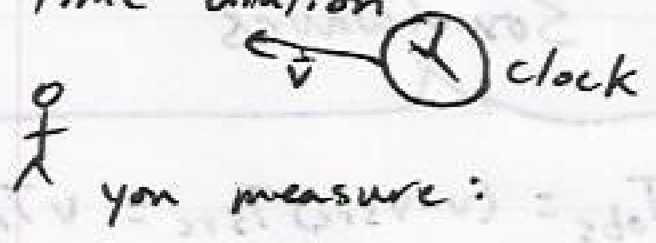


Measures

length of car measured when car is stationary

$L = L_o \underbrace{\sqrt{1 - v^2/c^2}}_{\text{always} \leq 1}$

Time dilation



you measure:

$\vec{v}$ = velocity of clock

The clock takes $\frac{T_o}{\sqrt{1-v^2/c^2}}$ seconds for the second-hand to advance T times.

From clock's point of view, you're moving at velocity $-\vec{v}$ and Your watch is slow by a factor of $\frac{1}{\sqrt{1-v^2/c^2}}$

Mass dilation

m_o

$m = \frac{m_o}{\sqrt{1-v^2/c^2}} = \overbrace{m_o \cdot \frac{1}{\sqrt{1-v^2/c^2}}}^{\gamma m_o}$

You measure.

objects velocity = $\vec{v}$

objects mass = m

object's mass at rest = m_o

$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} \geq 1$

$\lim_{v \to c} \gamma = \infty$

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Energy

$$K.E. = \underbrace{\overbrace{\sqrt{(m_0c^2)^2+(pc)^2}}^{E} - \overbrace{m_0c^2}^{\text{rest energy}}}$$

Kinetic energy

$$= m_0c^2\left(\sqrt{1+\left(\frac{p}{m_0c}\right)^2} - 1\right)$$

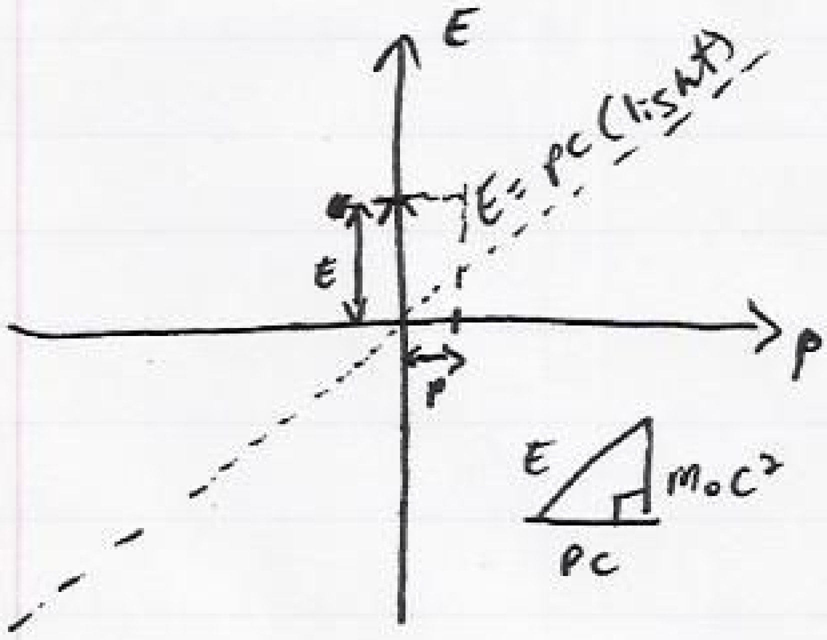
$E =$ Total mechanical energy $= \sqrt{(m_0c^2)^2+(pc)^2}$

(See Summary on pg 981)

Momentum:

$p = mv = m_0\gamma v$ for particles with positive mass

$p = \frac{E}{c}$ for photons



Lorentz invariants are things that don't contract or dilate even from point of view of (relativity) moving observers.

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m_0, c, [redacted]

$E^2 - (pc)^2 = (m_0c^2)^2$