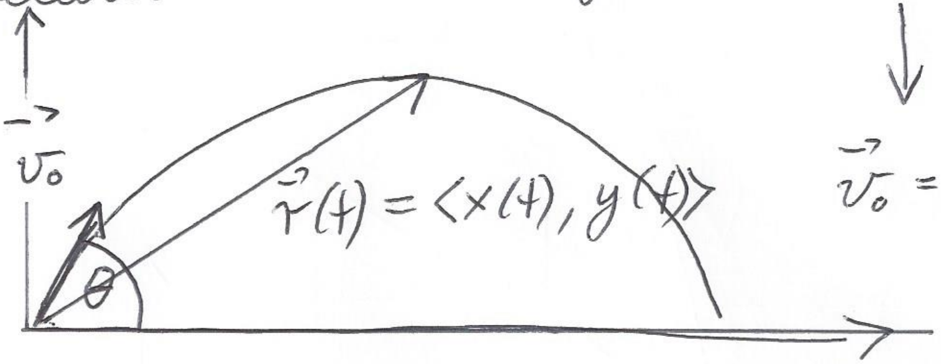
lecture 5 p-1

- Examples projectile motion
- Relative velocity
- Relativistic velocity, time



$\vec{v}_0 = \langle v_{0x}, v_{0y} \rangle$

$v_{0x} = v_0 \cos\theta$; $v_{0y} = v_0 \sin\theta$

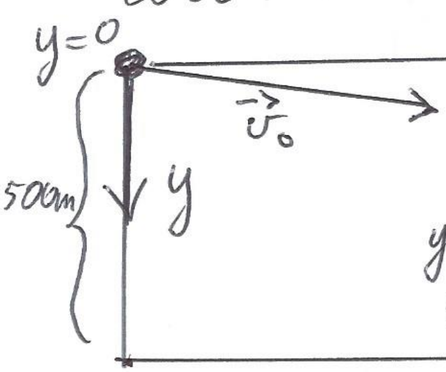
$x = v_{0x} \cdot t$; $v_x(t) = v_{0x}$;

$y = -\frac{1}{2} g t^2 + v_{0y} \cdot t + 0$

$v_y = -g t + v_{0y}$; $v_y^2 = v_{0y}^2 - 2 g y$

$v_0 = 50 \, m/s$ $\theta = 35^\circ$

Plane flying at a height of 500 m at an angle of 10° below the horizontal with $v_0 = 300 \, m/s$. It releases a package. Where will it land and with what velocity?



$\vec{v}_0 = \langle 300 \cdot \cos\theta, 300 \cdot \sin\theta \rangle$
$= \langle 295, 52.1 \rangle \frac{m}{s}$

$y(t) = \frac{1}{2} g t^2 + 52.1 \cdot t$

$500 = 4.9 t^2 + 52.1 \cdot t$

$$4.9t^2 + 52.1t - 500 = 0$$

$$t_{1,2} = \frac{-52.1 \pm \sqrt{52.1^2 + 4 \cdot 4.9 \cdot 500}}{9.8}$$

$$= \frac{-52.1 \pm 112}{9.8} \; ; \quad \underline{\underline{t = 6.10\ s}}$$

$x(t)$ $t = 6.00\,s$ is the horizontal distance

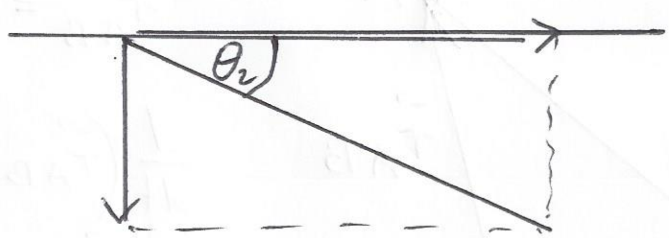
$$x(6.00\,s) = v_{0x} \cdot t = 295 \cdot 6.10 = \underline{\underline{1.80 \cdot 10^3\ m}}$$

With what velocity does it hit the ground?

$$v_{0x} = 295\ m/s \qquad v_{y} = v_{0y} + g\,t$$

$$= 52.1\ \frac{m}{s} + 9.8 \cdot 6.10\ \frac{m}{s} = 112\ \frac{m}{s}$$

$v_{0x} = v_x$



$$v = \sqrt{112^2 + 295^2} = 316\ \frac{m}{s}$$

$$\underline{\underline{\tan\theta_2 = \frac{112}{295} = 20.8^\circ}}$$

Relative velocity:

object A moves with 50 mph to the right

$$\vec{v}_{Ag} = 50\,\text{mph} \cdot \vec{i}$$

object B moves with 40 mph to the left.

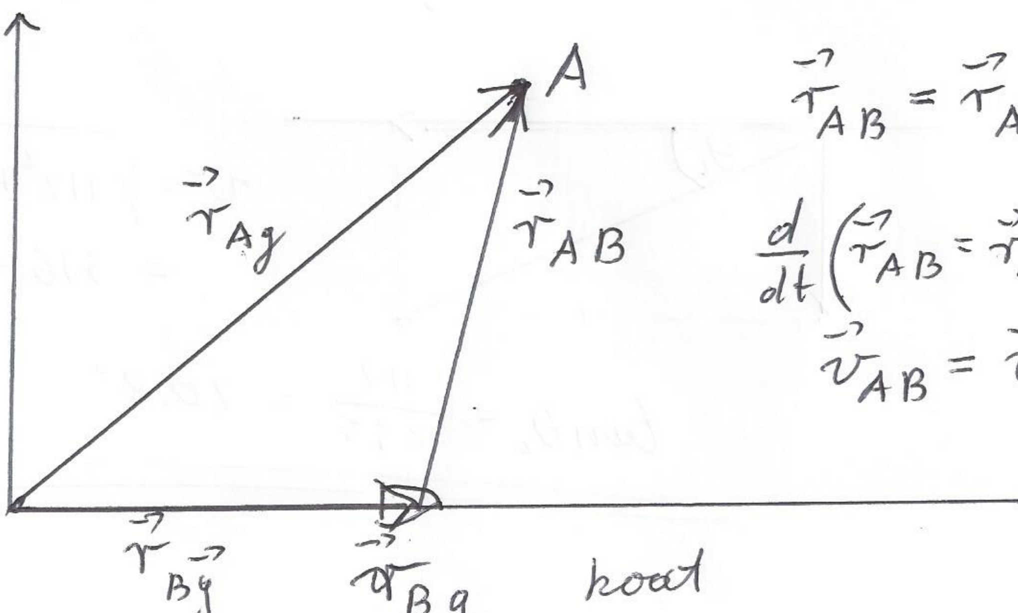
$$\vec{v}_{Bg} = -40\,\text{mph}\ \vec{i}$$

$$\vec{v}_{AB} = \vec{v}_{Ag} - \vec{v}_{Bg}$$

$$= 50\,\vec{i} - (-40\,\vec{i})$$

$$= 90\,\vec{i}$$

$$\vec{v}_{BA} = -\vec{v}_{AB}$$



$$\vec{r}_{AB} = \vec{r}_{Ag} - \vec{r}_{Bg}$$

$$\frac{d}{dt}\left(\vec{r}_{AB} = \vec{r}_{A} - \vec{r}_{B}\right)$$

$$\vec{v}_{AB} = \vec{v}_{Ag} - \vec{v}_{Bg}$$

$$\vec{v}_{Ag} = \langle 50\,\text{m/s}, -20\,\text{m/s} \rangle$$

$$\vec{v}_{Bg} = \langle -20\,\text{m/s}, 10\,\text{m/s} \rangle$$

Newtons laws apply only in non accelerated reference systems.

Equation R/ $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$ is only correct in non relativistic motions.

Einstein: no signal can travel faster than the speed of light $c = 3.000 \cdot 10^8 \frac{m}{s}$

$$\vec{v}_{AB} = \frac{\vec{v}_A - \vec{v}_B}{1 - \frac{\vec{v}_A \cdot \vec{v}_B}{c^2}}$$

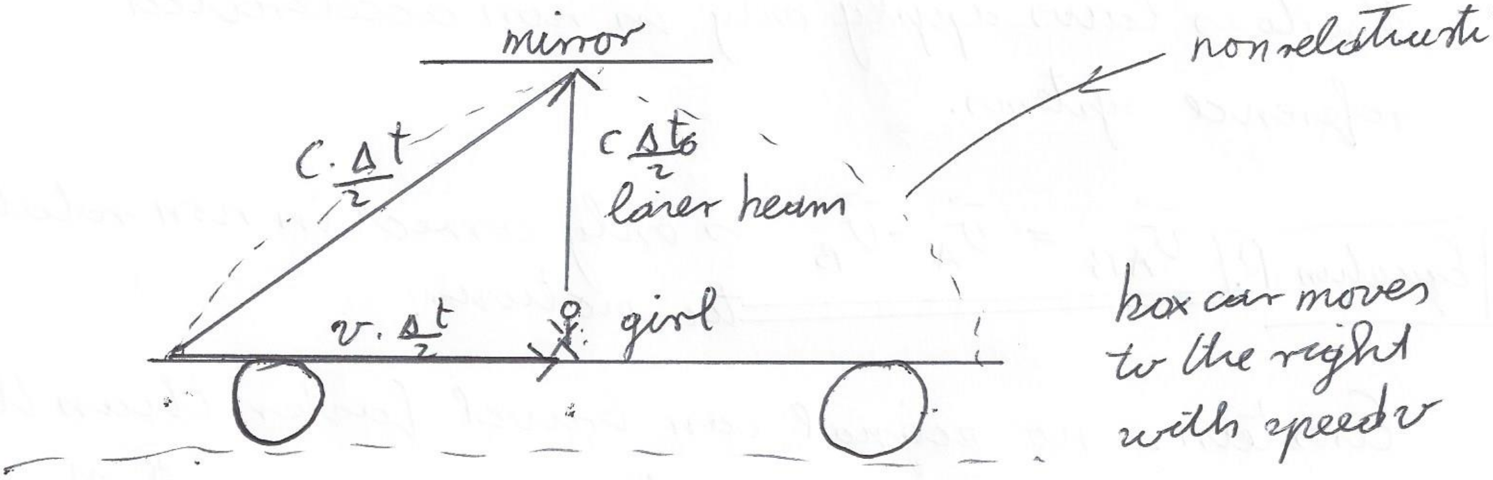
only correct in the same direction

$\vec{v}_A = 0.7 c \vec{i}$ $\vec{v}_B = -0.8 c \cdot \vec{i}$

$$\vec{v}_{AB} = \frac{0.7 c \vec{i} - (-0.8 c) \cdot \vec{i}}{1 - \frac{0.7 c \vec{i} \cdot (-0.8 c \vec{i})}{c^2}}$$

$$= \frac{1.5 c \vec{i}}{1 + \frac{0.7 c \cdot 0.8 c}{c^2}}$$

$$= \frac{1.5}{1.56} c \vec{i} = 0.962 c \vec{i}$$



Δt is the time the boy observes for the laser beam to come down.

$$\left(\frac{c \cdot \Delta t}{2}\right)^2 = \left(v \cdot \frac{\Delta t}{2}\right)^2 + \left(\frac{c \cdot \Delta t_0}{2}\right)^2$$

$$c^2 \Delta t^2 = v^2 \Delta t^2 + c^2 \Delta t_0$$

$$c^2 \Delta t_0^2 = c^2 \Delta t^2 - v^2 \Delta t^2 \quad \Big| \, c^2$$

$$\Delta t_0^2 = \Delta t^2 \left(1 - \frac{v^2}{c^2}\right)$$

$$\Delta t_0 = \Delta t \sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

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Moving clocks go slower!

Moving masses get "heavier"!

$$m(v) = \frac{m(v=0)}{\sqrt{1-\frac{v^2}{c^2}}};$$

rest mass is the mass measured in its own reference systems.

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

example: $v = 0.9999\,c$

$$\frac{1}{\sqrt{1-(0.9999)^2}} = 70.7$$

<u>energy</u> $E = m c^2 = m_0 \cdot \gamma \cdot c^2$

Chapter 4 Newton's laws

1) $\vec{v}$ constant in magnitude and direction

2) $$m\vec{a} = \sum \vec{F}_{ext}$$

$$\vec{a} = \frac{\sum \vec{F}_{ext}}{m}$$

$$m = \text{"}\left(\frac{\sum \vec{F}_{ext}}{\vec{a}}\right)\text{"}$$; <u>definition of mass</u>

$$= \frac{|\vec{F}_{ext}|}{|\vec{a}|}$$

3)

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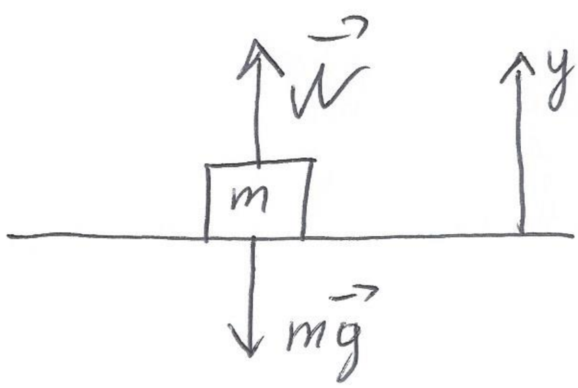
$$\vec{F}_{AB} = -\vec{F}_{BA}$$



$$\vec{N} + m\vec{g} = \vec{0}$$

$$N - mg = 0$$

$$N = mg$$