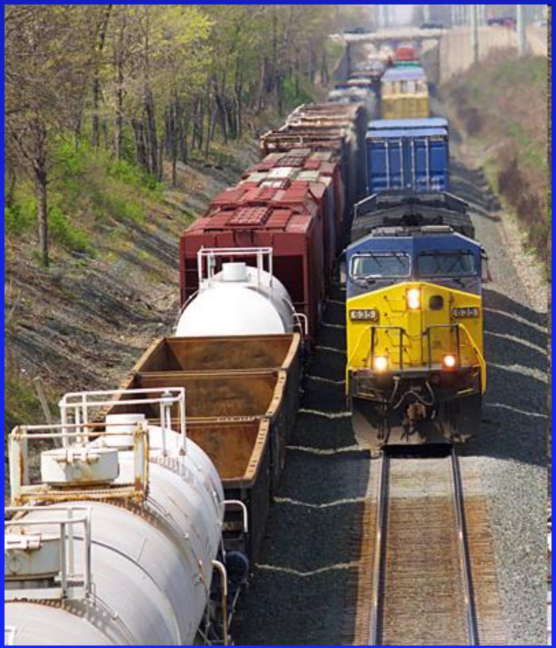
Physics 101: Lecture 07
More Constant Acceleration and Relative Velocity

-Textbook chapter 4.



Last Time

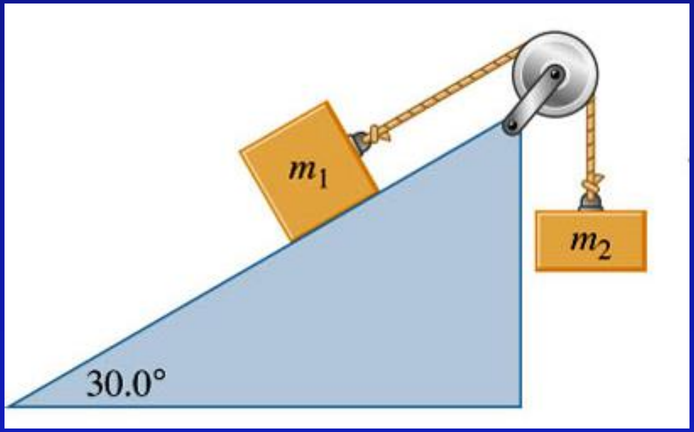
- X and Y directions are Independent!
  - ➔ Position, velocity and acceleration are vectors
- $F_{Net} = m\,a$ applies in both x and y direction
- Projectile Motion
  - ➔ $a_x = 0$ in horizontal direction
  - ➔ $a_y = -g$ in vertical direction

Today

- More 2-D Examples
- Newton's 3rd Law Review
- Relative Motion

Pulley, Incline and 2 blocks

A block of mass $m_1 = 2.6$ kg rests upon a frictionless incline as shown and is connected to mass m_1 via a flexible cord over an ideal pulley. What is the acceleration of block m_1 if $m_2 = 2.0$ kg?



X – direction $F_{Net,\,x} = m\,a_x$:

Block 1:

$$T - m_1 g \sin(30) = m_1 a_{1x}$$

$$T = m_1 g \sin(30) + m_1 a_{1x}$$

Y – direction $F_{Net,\,y} = m\,a_y$:

Block 2:

$$T - m_2\,g = m_2\,a_{2y}$$

Note: $a_{1x} = -\,a_{2y}$

Combine

$$T - m_2\,g = m_2\,a_{2y}$$

$$m_1 g \sin(30) + m_1 a_{1x} - m_2\,g = m_2\,a_{2y}$$

$$m_1 g \sin(30) + m_1 a_{1x} - m_2\,g = -m_2\,a_{1x}$$

$$m_1 a_{1x} + m_2 a_{1x} = m_2\,g - m_1 g \sin(30)$$

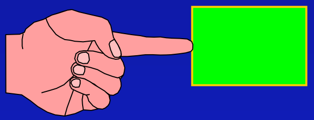
$$(m_1 + m_2)\,a_{1x} = g\,(m_2 - m_1 \sin(30))$$

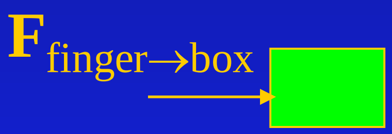
$$a_1 = g\,\frac{m_2 - m_1 \sin(30)}{m_1 + m_2}$$

$$\boxed{1.49\ \mathrm{m/s^2}}$$

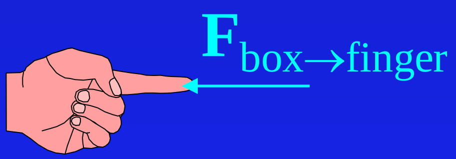
Newton's Third Law

➔ For every action, there is an equal and opposite reaction.





- Finger pushes on box
  - $\mathbf{F}_{finger \rightarrow box}$ = force exerted on box by finger



- Box pushes on finger
  - $\mathbf{F}_{box \rightarrow finger}$ = force exerted on finger by box

- Third Law:

$$\mathbf{F}_{box \rightarrow finger} = -\,\mathbf{F}_{finger \rightarrow box}$$

Newton's 3rd Law

Suppose you are an astronaut in outer space giving a brief push to a spacecraft whose mass is bigger than your own.

1) Compare the magnitude of the force you exert on the spacecraft, F_S, to the magnitude of the force exerted by the spacecraft on you, F_A, while you are pushing:

1. $F_A = F_S$ ← correct
2. $F_A > F_S$
3. $F_A < F_S$

Third Law!

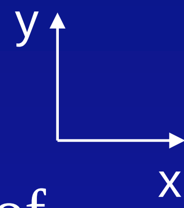
2) Compare the magnitudes of the acceleration you experience, a_A, to the magnitude of the acceleration of the spacecraft, a_S, while you are pushing:

1. $a_A = a_S$
2. $a_A > a_S$ ← correct
3. $a_A < a_S$

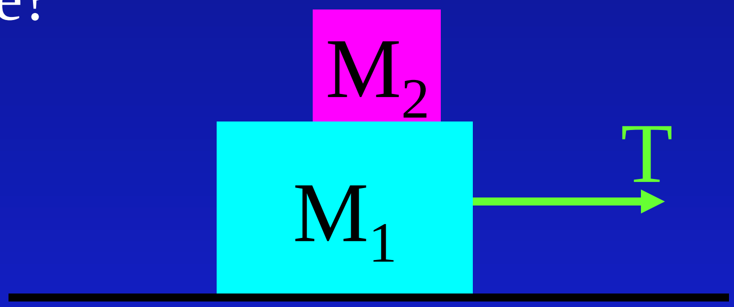
$a=F/m$

F same $\Rightarrow$ lower mass give larger a

Newton's 3rd Example



A rope attached to box 1 is accelerating it to the right at a rate of $3 m/s^2$ on a frictionless table. Friction keeps block 2 on top of block 1 w/o slipping. What is the tension in the rope?



X-direction: F = ma

Block 2: $f_{21} = m_2\, a_2$

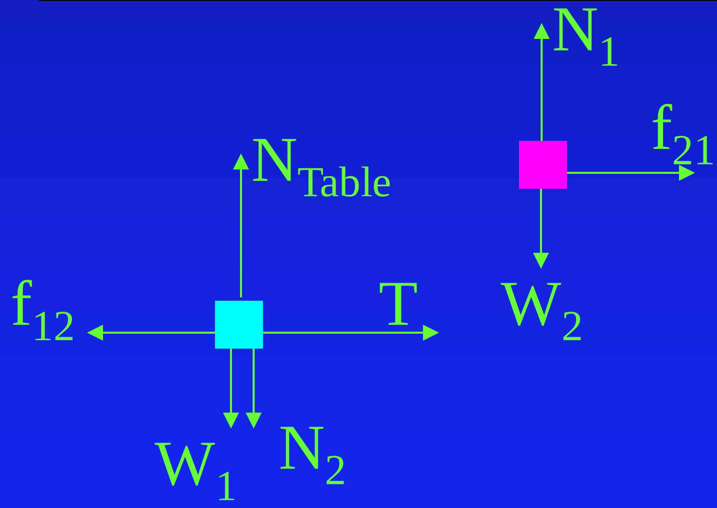
Block 1: $T - f_{12} = m_1\, a_1$

N3L says $|f_{12}| = |f_{21}|$

Combine: $T - m_2\, a_2 = m_1\, a_1$

$T = m_1\, a_1 + m_2\, a_2$

$= (m_1 + m_2)\, a$



- Same as if had one block $M = m_1 + m_2$!!!!

Relative Velocity

- Sometimes your velocity is known relative to a reference frame that is moving relative to the earth.
  - ➔ Example 1: A person moving relative to a train, which is moving relative to the ground.
  - ➔ Example 2: a plane moving relative to air, which is then moving relative to the ground.
- These velocities are related by vector addition:

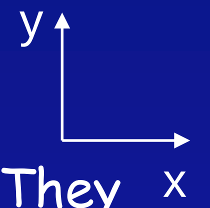
$$\vec{V}_{ac} = \vec{V}_{ab} + \vec{V}_{bc}$$

» v_{ac} is the velocity of the object relative to the ground

» v_{ab} is the velocity of the object relative to a moving reference frame

» v_{bc} is the velocity of the moving reference frame relative to the ground

Prelecture



Three swimmers can swim equally fast relative to the water. They have a race to see who can swim across a river in the least time. Relative to the water, Beth (B) swims perpendicular to the flow, Ann (A) swims upstream, and Carly (C) swims downstream. Which swimmer wins the race?

A) Ann 12%

B) Beth 58% ← correct

C) Carly 30%

"Flow is irrelevant in this situation, it's only a matter of how fast the swimmer can go in the y-direction"

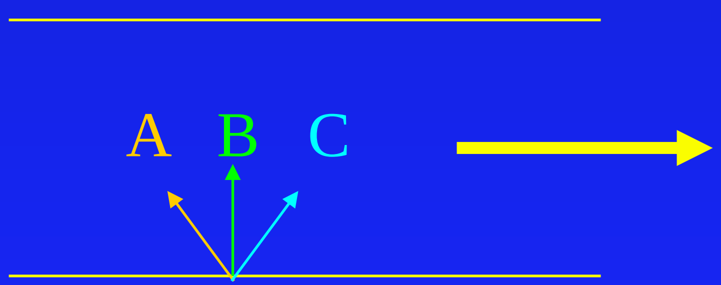
"I like Kielbasa"

$t = d / v_y$

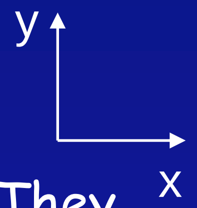
Ann $v_y = v \cos(\theta)$

Beth $v_y = v$

Carly $v_y = v \cos(\theta)$



ACT



Three swimmers can swim equally fast relative to the water. They have a race to see who can swim across a river in the least time. Relative to the water, Beth (B) swims perpendicular to the flow, Ann (A) swims upstream, and Carly (C) swims downstream. Who gets second? Ann or Carly?

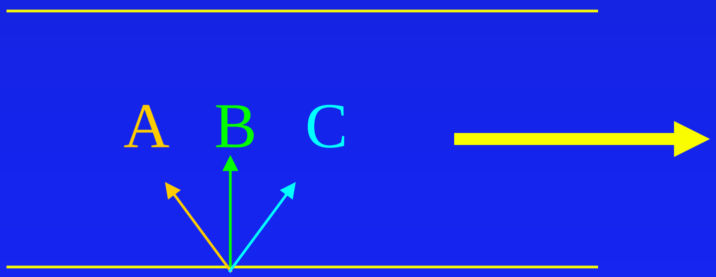
A) Ann
B) Same
C) Carly

$t = d / v_y$

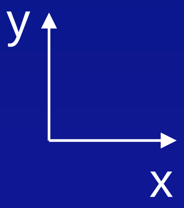
Ann $v_y = v \cos(\theta)$

Beth $v_y = v$

Carly $v_y = v \cos(\theta)$

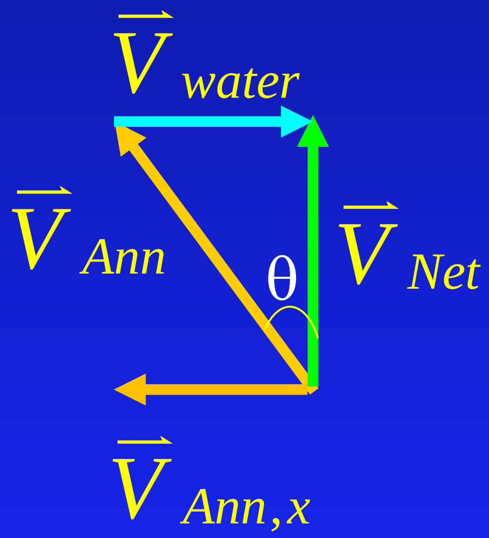


Swimmer Example



What angle should Ann take to get directly to the other side if she can swim 5 mph relative to the water, and the river is flowing at 3 mph?

$$\vec{V}_{Net} = \vec{V}_{Ann} + \vec{V}_{water}$$



x-direction

$0 = -V_{Ann,\,x} + V_{water}$

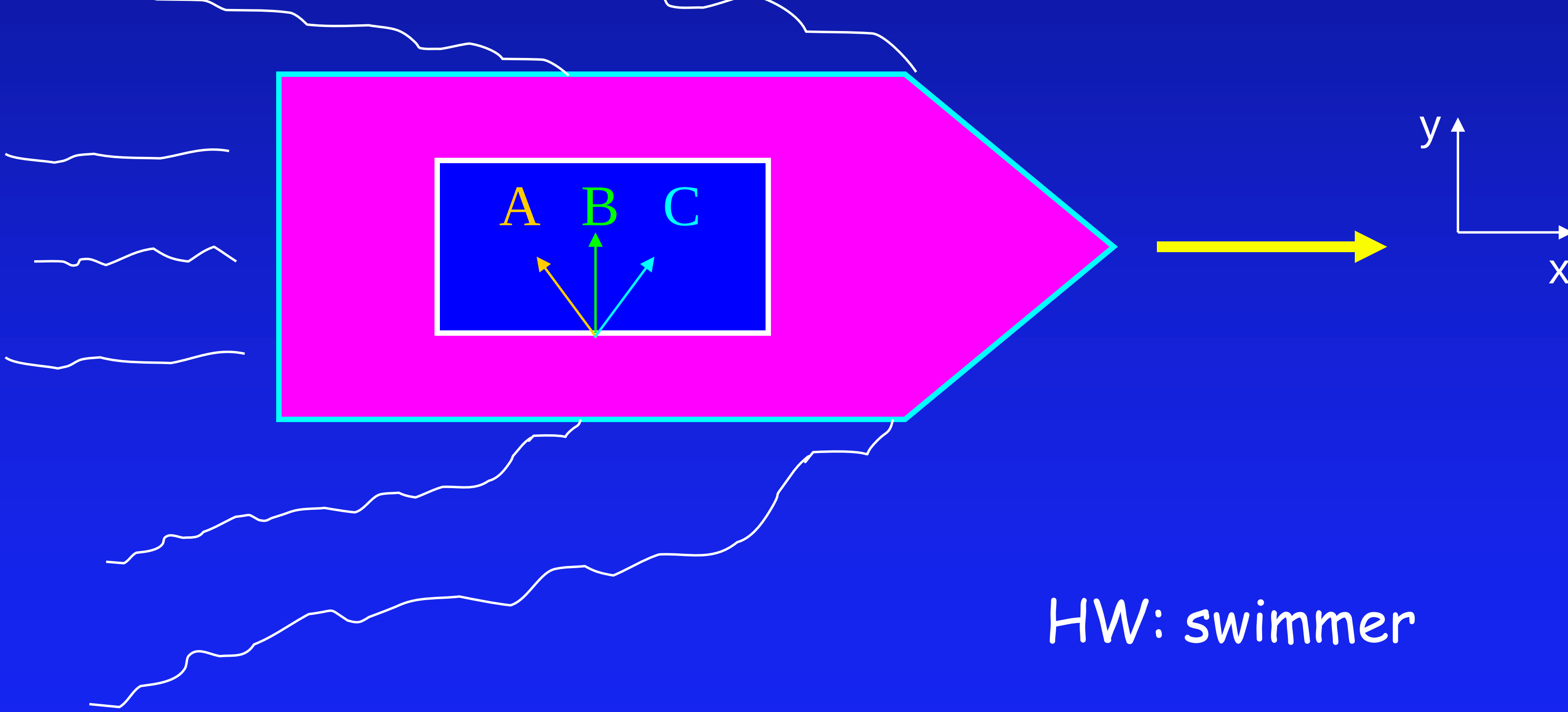
$0 = -V_{Ann} \sin(\theta) + 3$

$5 \sin(\theta) = 3$

$\sin(\theta) = 3/5 \Rightarrow \theta = 37^{o}$

Think of a swimming pool on a cruise ship

When swimming to the other side of the pool,
you don't worry about the motion of the ship !



HW: swimmer

Demo - bulldozer

Summary of Concepts

- X and Y directions are Independent!
  - ➔Position, velocity and acceleration are vectors
- $F_{Net} = m\,a$ applies in both x and y direction
- Newton's 3rd Law
- Relative Motion (Add vector components)

$$\vec{V}_{sg} = \vec{V}_{sw} + \vec{V}_{wg}$$