

Physics 101: Lecture 03

Kinematics



Today's lecture will cover
Textbook Sections 3.1-3.3
(and some Ch. 4)

Force at Angle Example

- A person is pushing a 15 kg block across a floor with $\mu_k = 0.4$ at a constant speed. If she is pushing down at an angle of 25 degrees, what is the magnitude of her force on the block?

x- direction: $\Sigma F_x = ma_x$

$$F_{\text{push}} \cos(\theta) - F_{\text{friction}} = 0$$

$$F_{\text{push}} \cos(\theta) - \mu F_{\text{Normal}} = 0$$

$$F_{\text{Normal}} = F_{\text{push}} \cos(\theta) / \mu$$

y- direction: $\Sigma F_y = ma_y$

$$F_{\text{Normal}} - F_{\text{weight}} - F_{\text{Push}} \sin(\theta) = 0$$

$$F_{\text{Normal}} - mg - F_{\text{Push}} \sin(\theta) = 0$$

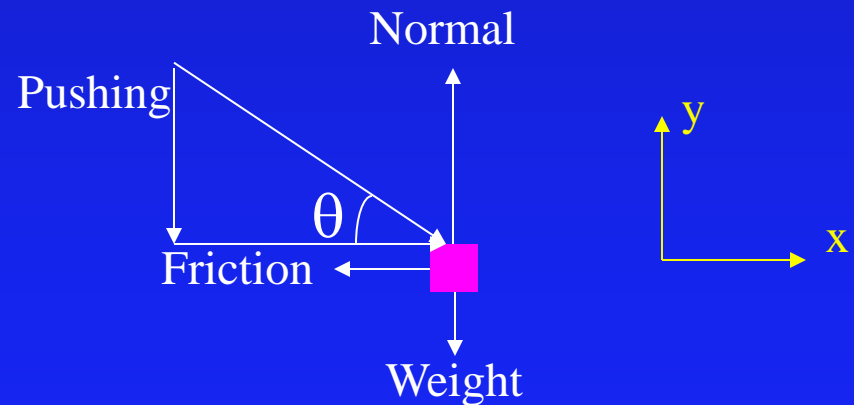
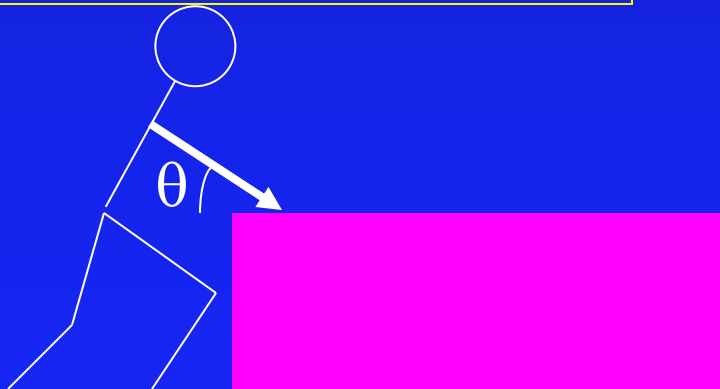
Combine:

$$(F_{\text{push}} \cos(\theta) / \mu) - mg - F_{\text{Push}} \sin(\theta) = 0$$

$$F_{\text{push}} (\cos(\theta) / \mu - \sin(\theta)) = mg$$

$$F_{\text{push}} = mg / (\cos(\theta) / \mu - \sin(\theta))$$

$$F_{\text{push}} = 80 \text{ N}$$



Tension Example:

- Determine the force exerted by the hand to suspend the 45 kg mass as shown in the picture.

A) 220 N B) 440 N C) 660 N

D) 880 N E) 1100 N

$$\Sigma F = m a$$

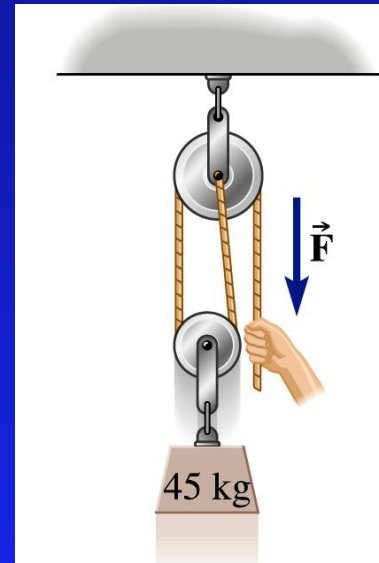
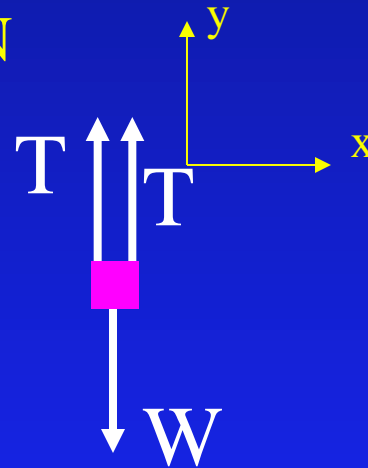
$$T + T - W = 0$$

$$2 T = W$$

$$T = m g / 2$$

$$= (45 \text{ kg} \times 9.8 \text{ m/s}^2) / 2$$

$$= 220 \text{ N}$$



- Remember the magnitude of the tension is the same everywhere along the rope!

Overview

- Kinematics: Description of Motion
 - ➔ Position and displacement
 - ➔ velocity
 - » average
 - » instantaneous
 - ➔ Acceleration
 - » average
 - » instantaneous
 - ➔ Relative velocity (first pass)

Position vs Time Plots

- Gives location at any time.
- Displacement is change in position.
- Slope gives instantaneous velocity.

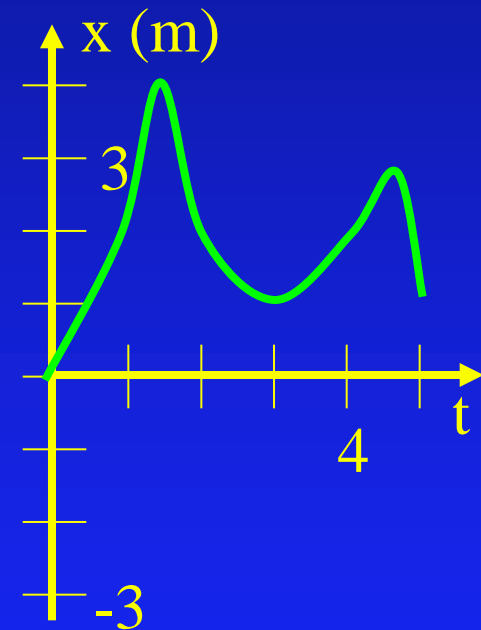
Position at $t=3$, $x(3) = 1$

Displacement between $t=5$ and $t=1$. $\Delta x = -1.0$ m

$$1.0 \text{ m} - 2.0 \text{ m} = -1.0 \text{ m}$$

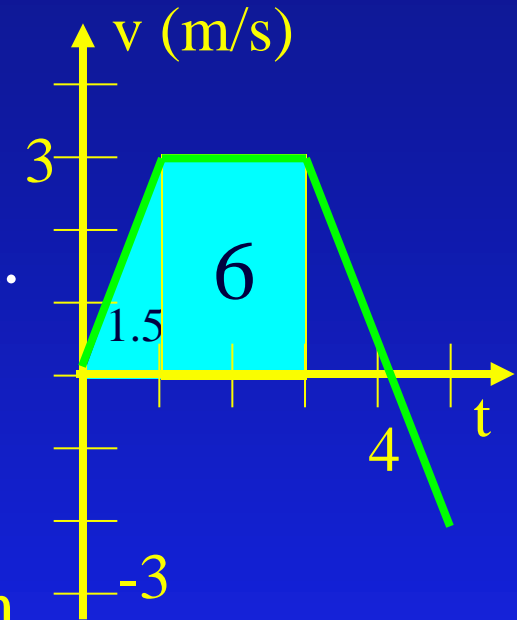
Average velocity between $t=5$ and $t=1$. $v = -0.25$ m/s

$$-1 \text{ m} / 4 \text{ s} = -0.25 \text{ m/s}$$



Velocity vs Time Plots

- Gives velocity at any time.
- Area gives displacement
- Slope gives instantaneous acceleration.



velocity at $t=2$, $v(2) = 3 \text{ m/s}$

Displacement between $t=0$ and $t=3$: $\Delta x = 7.5 \text{ m}$

$$t=0 \text{ to } t=1: \frac{1}{2} (3 \text{ m/s}) (1 \text{ s}) = 1.5 \text{ m}$$

$$t=1 \text{ to } t=3: (3 \text{ m/s}) (2 \text{ s}) = 6 \text{ m}$$

Average velocity between $t=0$ and $t=3$? $v = 7.5 \text{ m} / 3 \text{ s} = 2.5 \text{ m/s}$

Change in v between $t=5$ and $t=3$. $\Delta v = -2 \text{ m/s} - 3 \text{ m/s} = -5 \text{ m/s}$

Average acceleration between $t=5$ and $t=3$: $a = -5 \text{ m/s} / (2 \text{ s}) = -2.5 \text{ m/s}^2$

Acceleration vs Time Plots

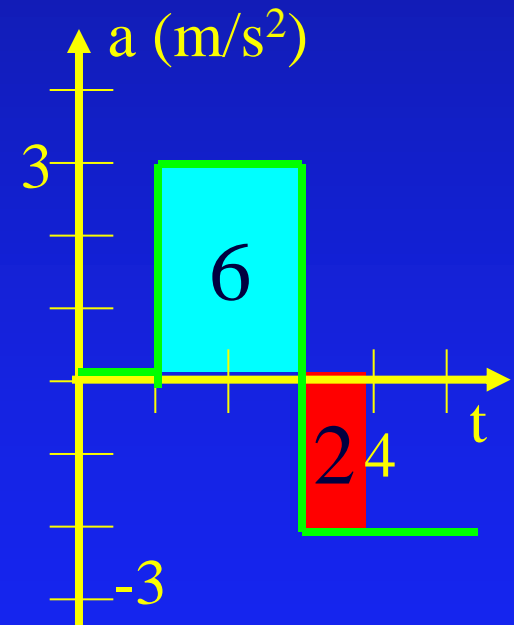
- Gives acceleration at any time.
- Area gives change in velocity

Acceleration at $t=4$, $a(4) = -2 \text{ m/s}^2$

Change in v between $t=4$ and $t=1$. $\Delta v = +4 \text{ m/s}$

$$t=1-3: \Delta v = (3 \text{ m/s}^2)(2 \text{ s}) = 6 \text{ m/s}$$

$$t=3-4: \Delta v = (-2 \text{ m/s}^2)(1 \text{ s}) = -2 \text{ m/s}$$



Acceleration Preflights

Is it possible for an object to have a positive velocity at the same time as it has a negative acceleration?

91% 1 - Yes "the object could be slowing down."

9% 2 - No "if the velocity is constant then the acceleration is zero"

If the velocity of some object is not zero, can its acceleration ever be zero ?

95% 1 - Yes "The velocity could be non-zero and constant. A constant velocity has no acceleration.."

5% 2 - No

Velocity ACT

If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

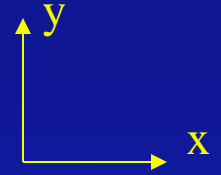
A - Yes

B - No

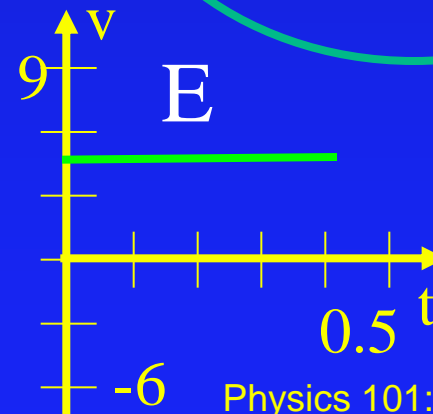
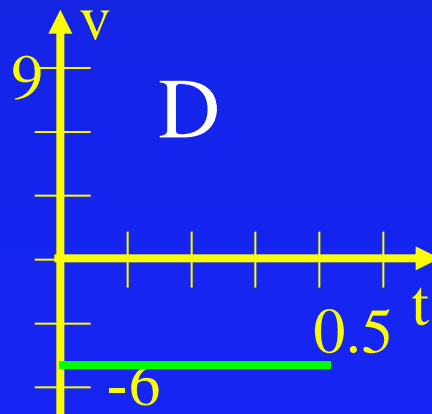
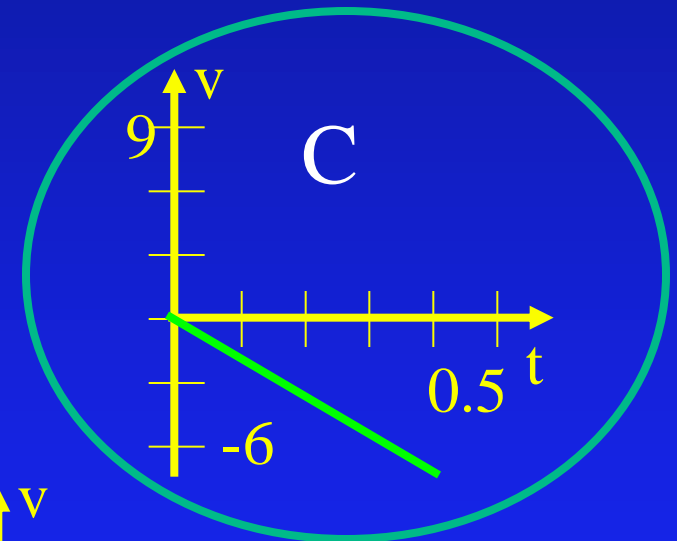
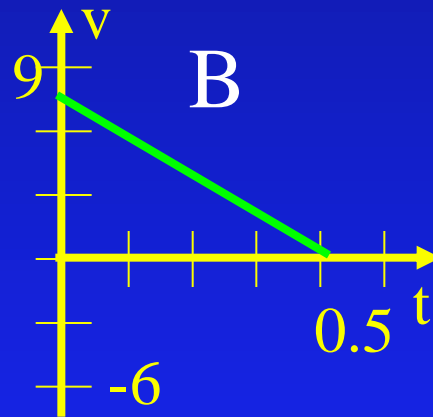
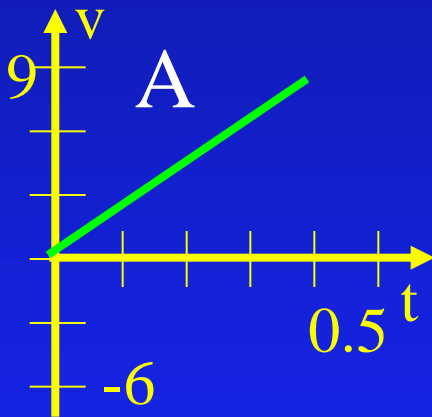
Drive north 5 miles, put car in reverse and drive south 2 miles. Average velocity is positive.

Dropped Ball

- A ball is dropped from a height of two meters above the ground.



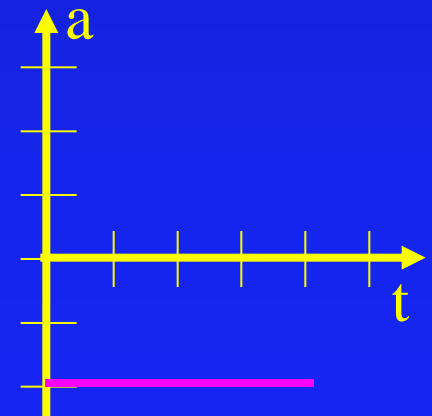
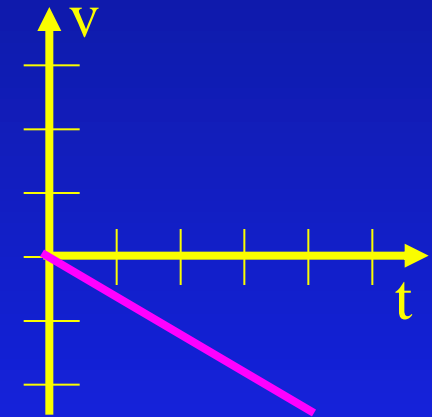
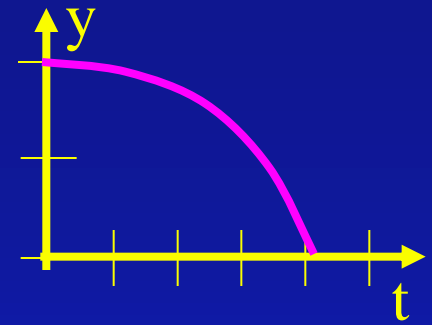
- Draw v_y vs t



Dropped Ball

A ball is dropped for a height of two meters above the ground.

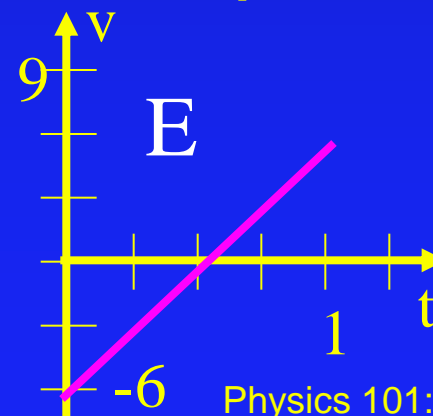
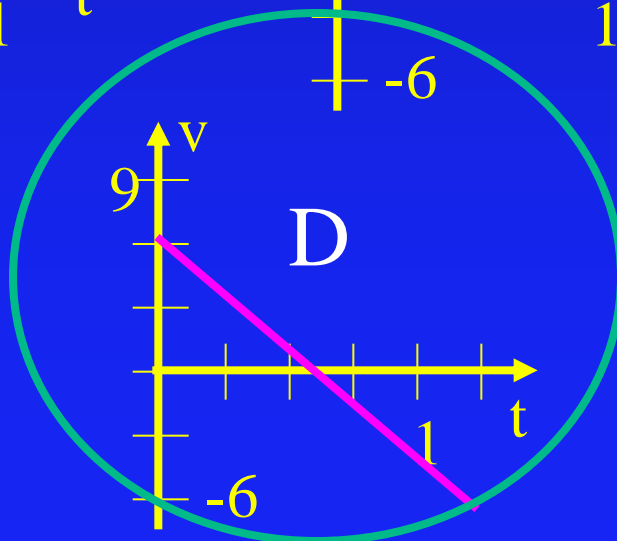
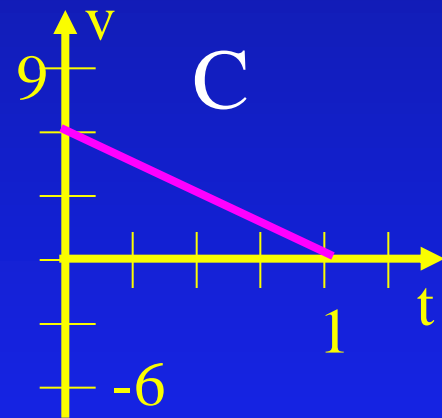
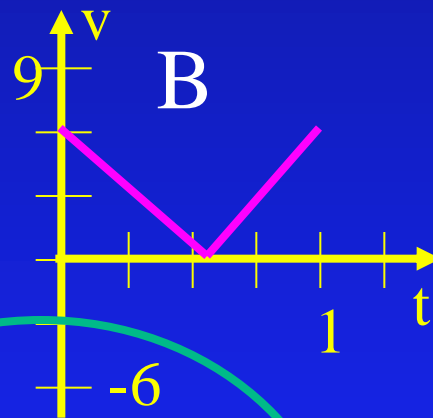
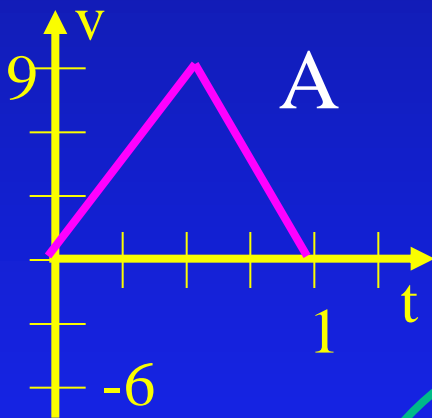
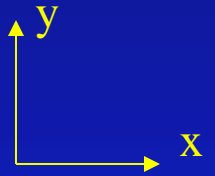
- Draw v vs t
- Draw y vs t
- Draw a vs t



Tossed Ball

- A ball is tossed from the ground up a height of two meters above the ground. And falls back down

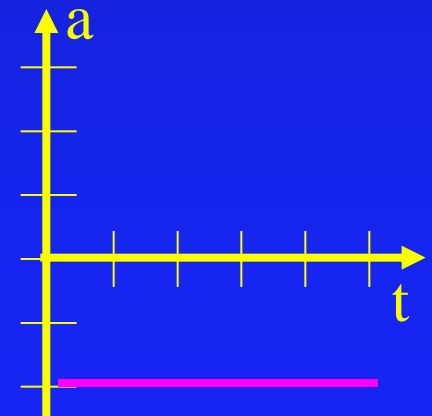
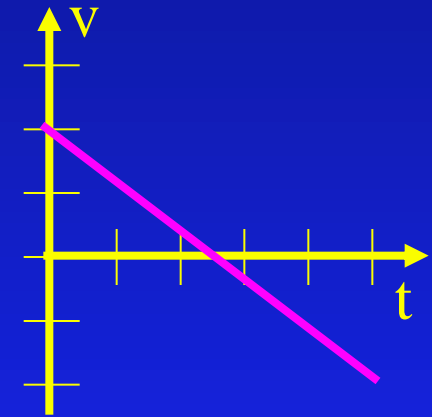
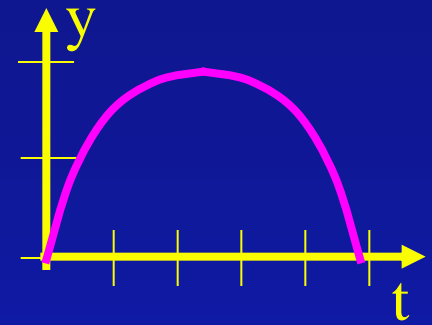
● Draw v vs t



Tossed Ball

• A ball is tossed from the ground up a height of two meters above the ground. And falls back down

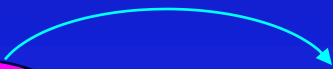
- Draw v vs t
- Draw y vs t
- Draw a vs t



ACT

A ball is thrown straight up in the air and returns to its initial position. During the time the ball is in the air, which of the following statements is true?

- A - Both average acceleration and average velocity are zero.
- B - Average acceleration is zero but average velocity is not zero.
- C - Average velocity is zero but average acceleration is not zero.
- D - Neither average acceleration nor average velocity are zero.

$$V_{ave} = \Delta Y / \Delta t = (Y_f - Y_i) / (t_f - t_i) = 0$$


$$a_{ave} = \Delta V / \Delta t = (V_f - V_i) / (t_f - t_i)$$

Not 0 since V_f and V_i are not the same!

Relative Velocity (first pass)

You are on a train traveling 40 mph North. If you walk 5 mph toward the front of the train, what is your speed relative to the ground?

A) 45 mph

B) 40 mph

C) 35 mph

$$40 \text{ mph N} + 5 \text{ mph N} = 45 \text{ mph N}$$



Relative Velocity

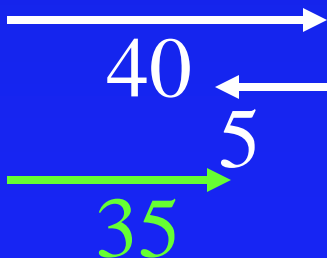
You are on a train traveling 40 mph North. If you walk 5 mph toward the rear of the train, what is your speed relative to the ground?

A) 45 mph

B) 40 mph

C) 35 mph

$$40 \text{ mph N} - 5 \text{ mph N} = 35 \text{ mph N}$$



Relative Velocity

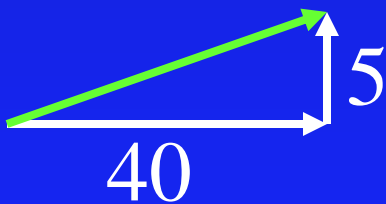
You are on a train traveling 40 mph North. If you walk 5 mph sideways across the car, what is your speed relative to the ground?

A) < 40 mph

B) 40 mph

C) > 40 mph

$$40 \text{ mph N} + 5 \text{ mph W} = 41 \text{ mph N}$$



$$|v| = \sqrt{40^2 + 5^2}$$

Relative Velocity

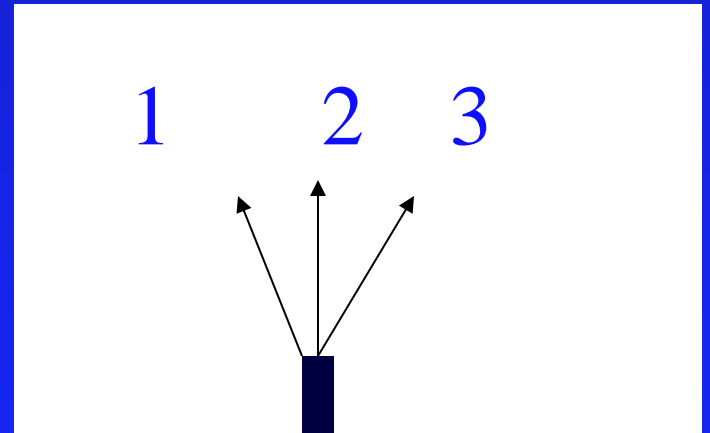
- Sometimes your velocity is known relative to a reference frame that is moving relative to the earth.
 - ➔ Example 1: A person moving relative to a train, which is moving relative to the ground.
 - ➔ Example 2: a plane moving relative to air, which is then moving relative to the ground.
- These velocities are related by vector addition:
 - » \vec{v}_{ac} is the velocity of the object relative to the ground
 - » \vec{v}_{ab} is the velocity of the object relative to a moving reference frame
 - » \vec{v}_{bc} is the velocity of the moving reference frame relative to the ground

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

Tractor Demo 1

Which direction should I point the tractor to get it across the table fastest?

- A) 30 degrees left
- B) Straight across
- C) 30 degrees right



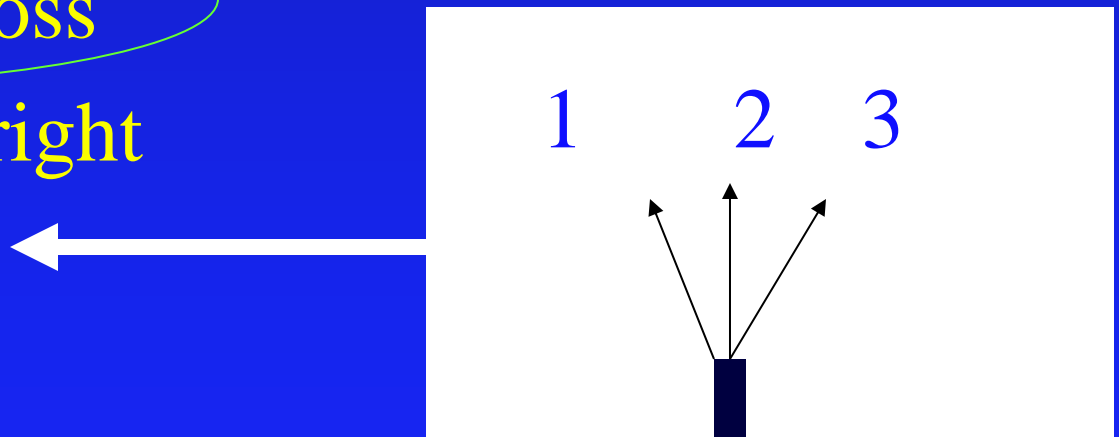
Tractor Demo (moving table)

- Which direction should I point the tractor to get it across the table fastest?

A) 30 degrees left

B) Straight across

C) 30 degrees right



Summary of Concepts

- kinematics: A description of motion
- position: *your coordinates*
- displacement: $\Delta x = \text{change of position}$
- velocity: *rate of change of position*
 - ➔ average : $\Delta x / \Delta t$
 - ➔ instantaneous: slope of x vs. t
- acceleration: *rate of change of velocity*
 - ➔ average: $\Delta v / \Delta t$
 - ➔ instantaneous: slope of v vs. t
- relative velocity: $v_{ac} = v_{ab} + v_{bc}$