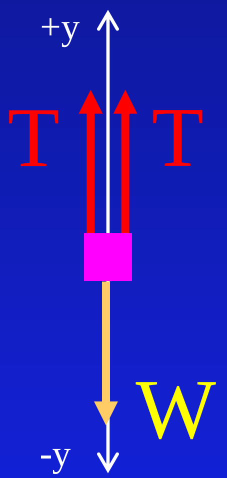
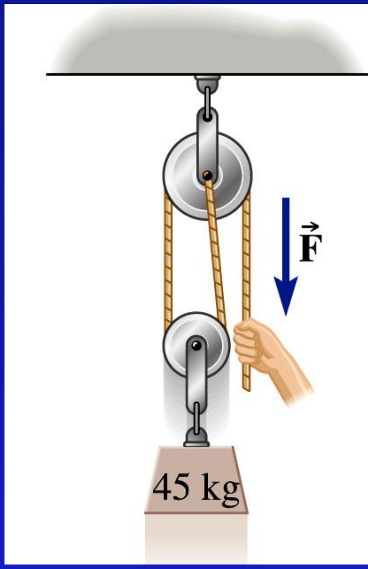
Physics 101: Lecture 03
Kinematics

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

A Refresher:

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

Step 1 – Draw!

Step 2 – Forces!

Step 3 – Newton's 2nd!

$F_{Net} = ma = 0$ equilibrium!

$T + T - W = 0$

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

Force at Angle Example

A person is pushing a 15 kg block across a floor with $\mu_k = 0.4$ at a ***constant speed (a=0)***. If she is pushing down at an angle of 25 degrees, what is the magnitude of her force on the block?

x- direction: $F_{Net,\,x} = ma_x$

$$P_x - f = 0$$

$$P\cos(\theta) - \mu_k N = 0$$

$$N = P\cos(\theta) / \mu_k$$

y- direction: $F_{Net,\,y} = ma_y$

$$N - W - P_y = 0$$

$$N - mg - P\sin(\theta) = 0$$

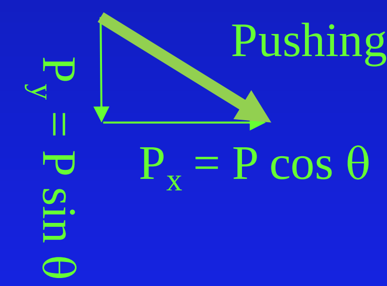
Combine:

$$(P\cos(\theta) / \mu_k) - mg - P\sin(\theta) = 0$$

$$P\,[\cos(\theta) / \mu_k - \sin(\theta)] = mg$$

$$P = mg / [\cos(\theta)/\mu_k - \sin(\theta)]$$

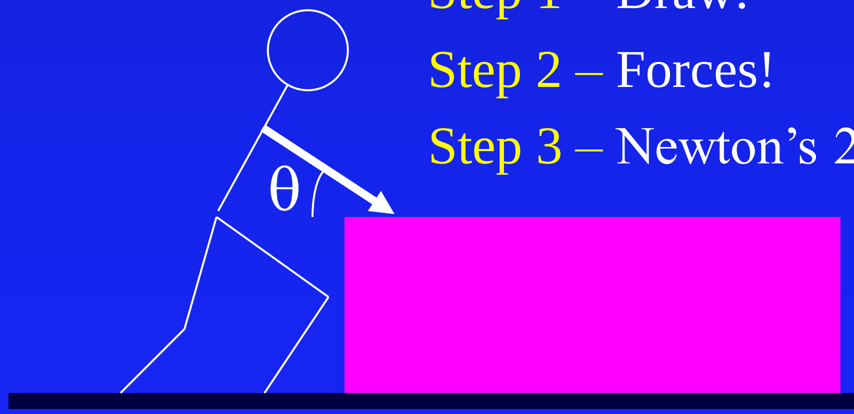
$$P = 80\text{ N}$$

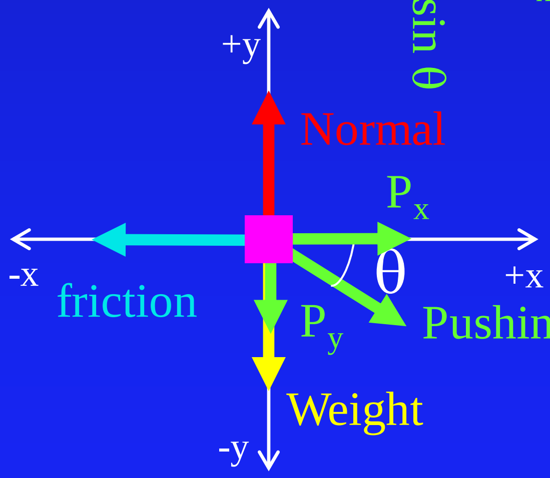


Step 1 – Draw!

Step 2 – Forces!

Step 3 – Newton's 2nd!



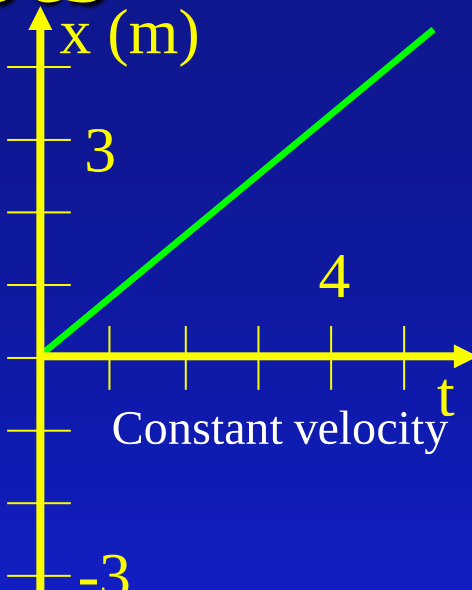


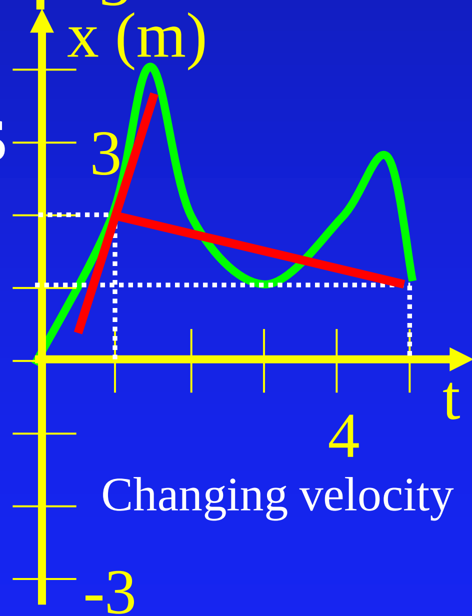
Today: An Overview

- What happens when a $\neq 0$?
- Kinematics: Description of Motion
  - ➔ Position and Displacement
  - ➔ Velocity
    - » average
    - » instantaneous
  - ➔ Acceleration
    - » average
    - » instantaneous
  - ➔ Relative velocity (first pass)

Position vs Time Plots

- DISPLACEMENT is change in position, $\Delta x = x_f - x_0$.
- VELOCITY is rate of change of position, $v = \Delta x / \Delta t$ = slope
- Slope between any two points gives average velocity at that point
- Slope of tangent line at any point gives instantaneous velocity at that point.





Displacement between t=5 and t=1:

$$\Delta x = x_f - x_0$$

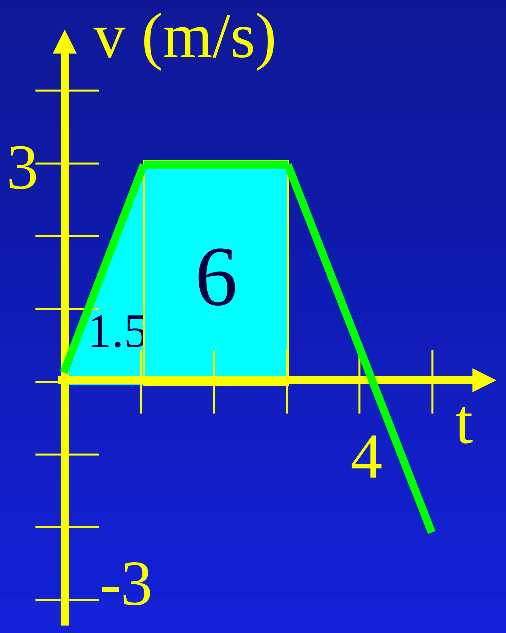
$$\Delta x = 1.0 \text{ m} - 2.0 \text{ m} = -1.0 \text{ m}$$

Average velocity between t=5 and t=1. $v = \Delta x / \Delta t$

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

Velocity vs Time Plots

- Gives velocity at any time.
- Area gives displacement
  - ➔ $v = \Delta x/\Delta t$ => $\Delta x = v \, \Delta t$
- Slope at any point gives <u>instantaneous</u> acceleration.



velocity at t=2, v(2) = 3 m/s

Displacement between t=0 and t=3: Δx= 7.5 m

t=0 to t=1: ½ (3m/s) (1 s) = 1.5 m

t=1 to t=3: (3m/s) (2 s) = 6 m

Average velocity between t=0 and t=3? v= 7.5 m / 3s = 2.5 m/s

Change in v between t=5 and t=3. Δv = -2 m/s – 3 m/s = -5 m/s

<u>Average</u> acceleration between t=5 and t=3: a = -5 m/s / (2 s) = -2.5 m/s^2

Acceleration vs Time Plots

- Gives acceleration at any time.

  $a = \Delta v/\Delta t$

- Area gives change in velocity

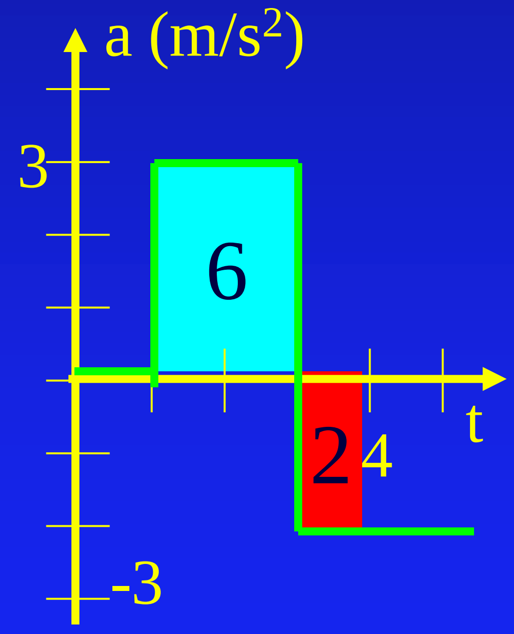
  $a = \Delta v/\Delta t \quad \Rightarrow \quad \Delta v = a\,\Delta t$

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

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

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

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



Acceleration Checkpoints

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

1 - Yes

2 - No

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

1 - Yes

2 - No

Velocity ACT

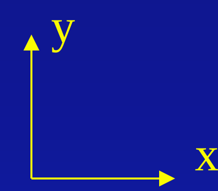
If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

A - Yes

B - No

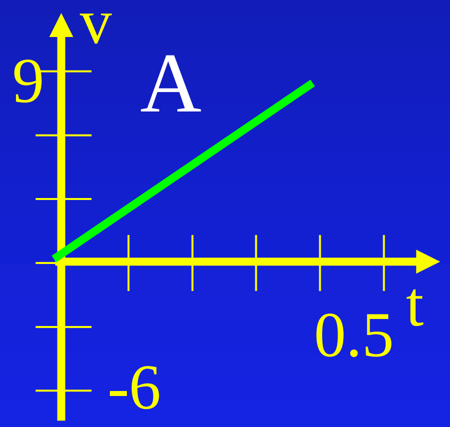
Drive north 5 miles, put car in reverse and drive south 2 miles. Average velocity is positive.

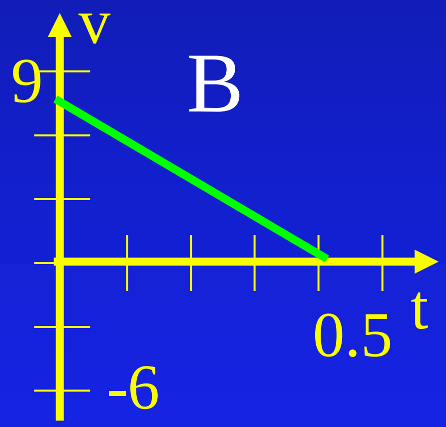
Dropped Ball

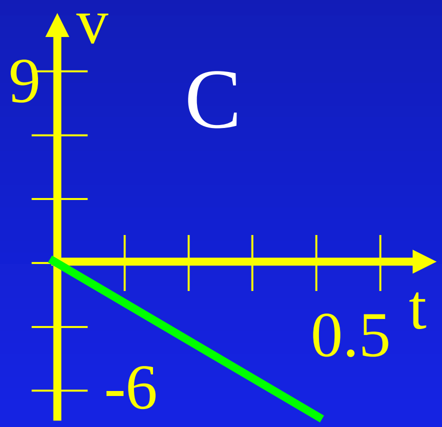


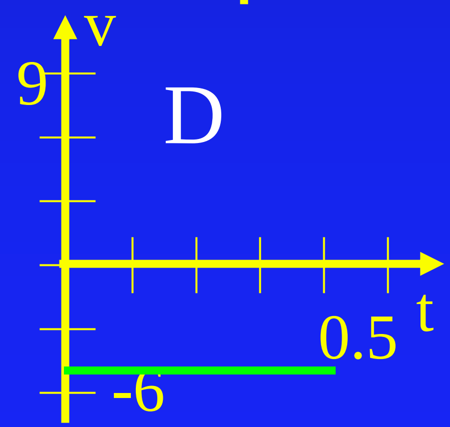
- A ball is dropped from a height of two meters above the ground.

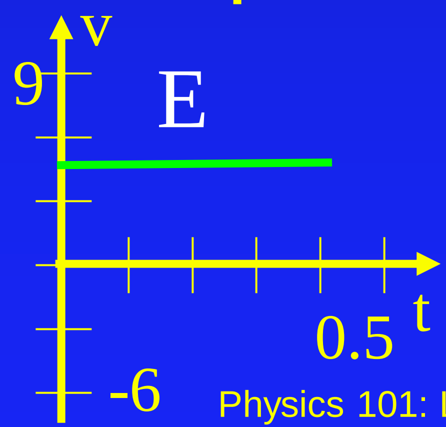
- Draw v_y vs t





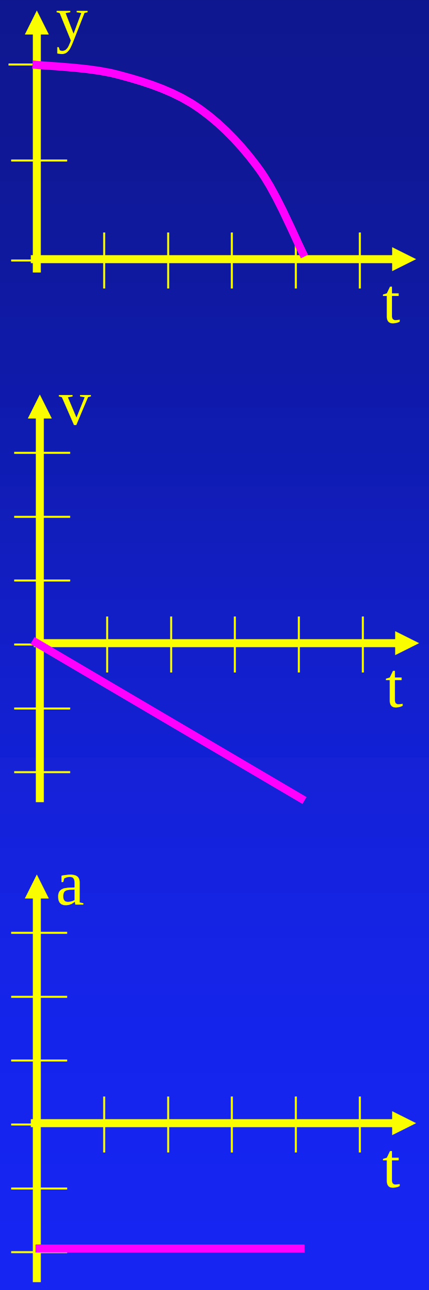






Dropped Ball

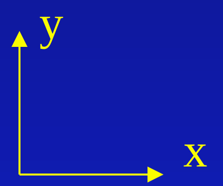
A ball is dropped for a height of two meters above the ground.



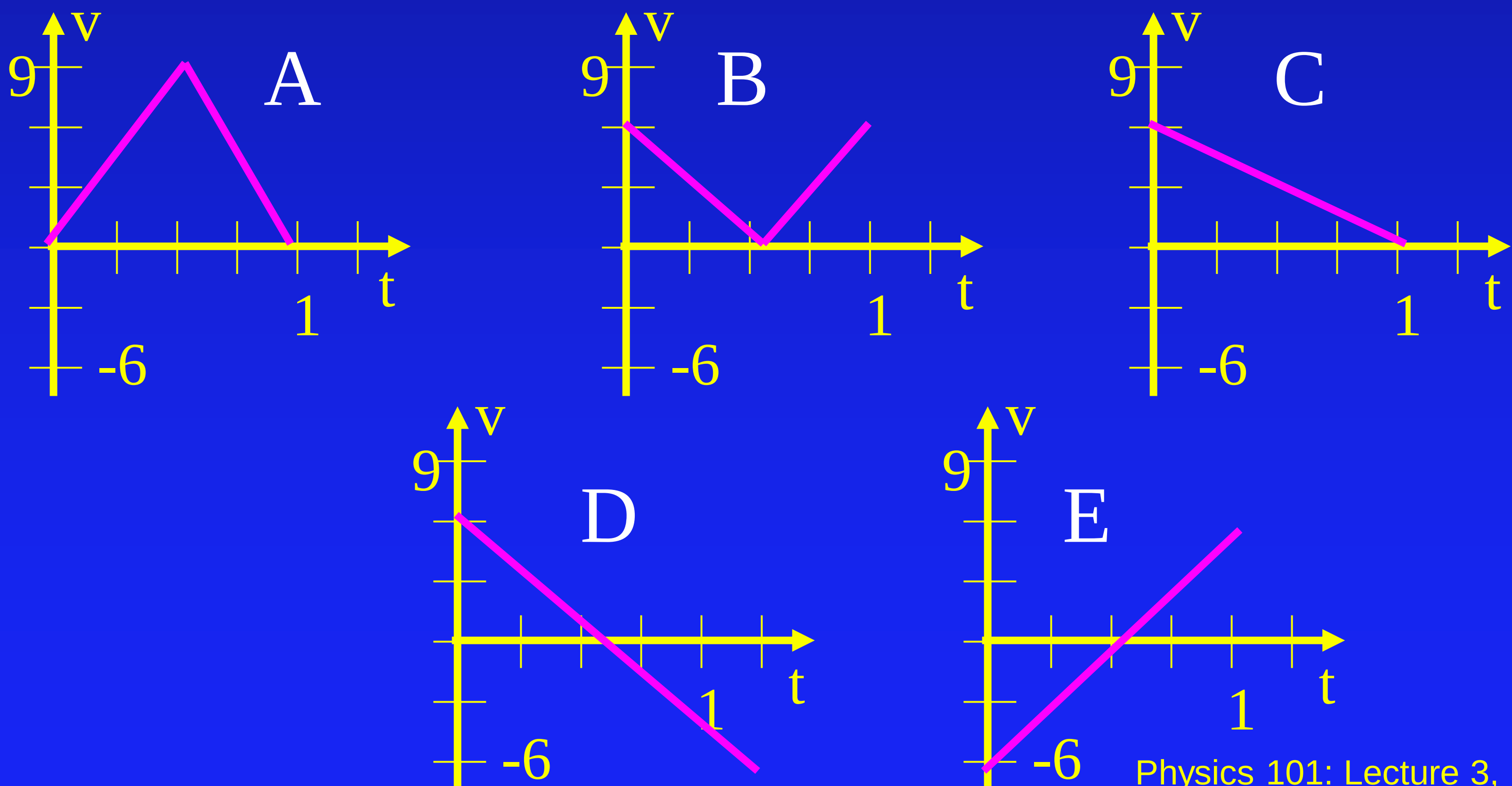
- Draw v vs t
- Draw y vs t
- Draw a vs t

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



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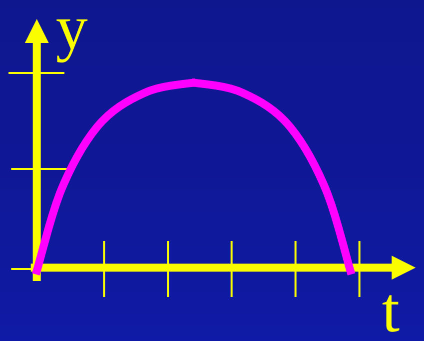
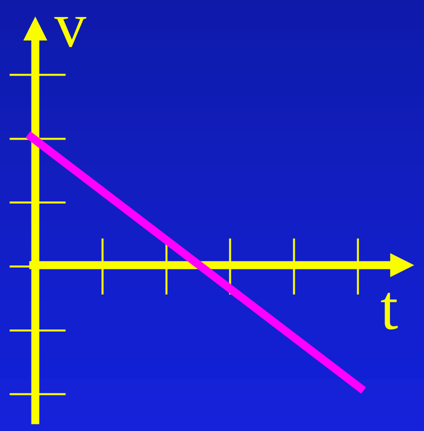
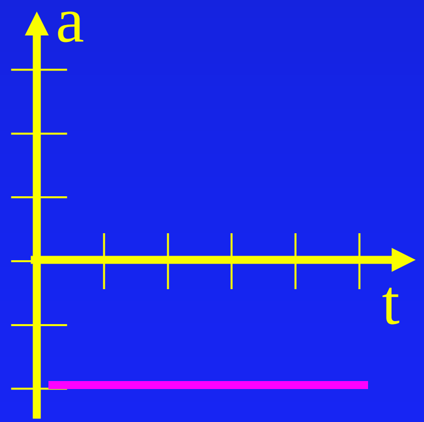






ACT

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.

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

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

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

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

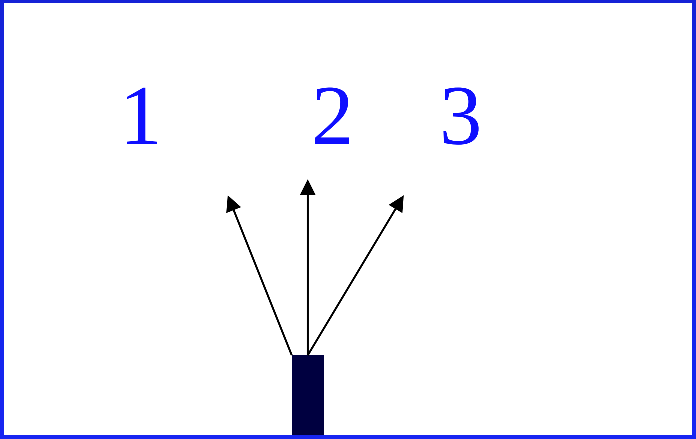
Tractor Demo 1

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



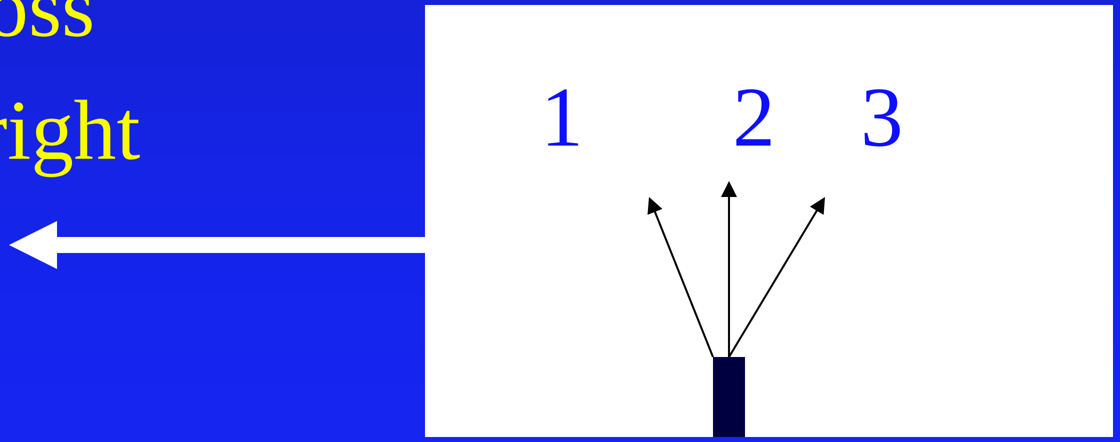
Tractor Demo (moving table)

- 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: Δx = 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: $v_{ac} = v_{ab} + v_{bc}$