Physics 101: Lecture 03
Kinematics

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

- You had homework due yesterday morning!
- But Monday was Labor Day, and there were no office hours :(
- So:

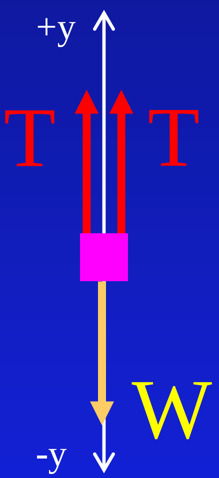
POINTS!!!

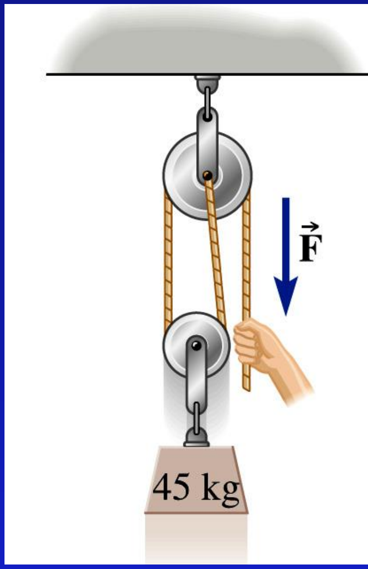
A Refresher:

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!

$T + T - W = 0$ $2T = W$ $T = mg/2 = 220$ N

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

$N - W - P_y = 0$

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

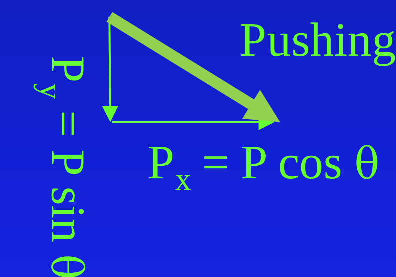
Combine:

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

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

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

P = 80 N



Step 1 – Draw!

Step 2 – Forces!

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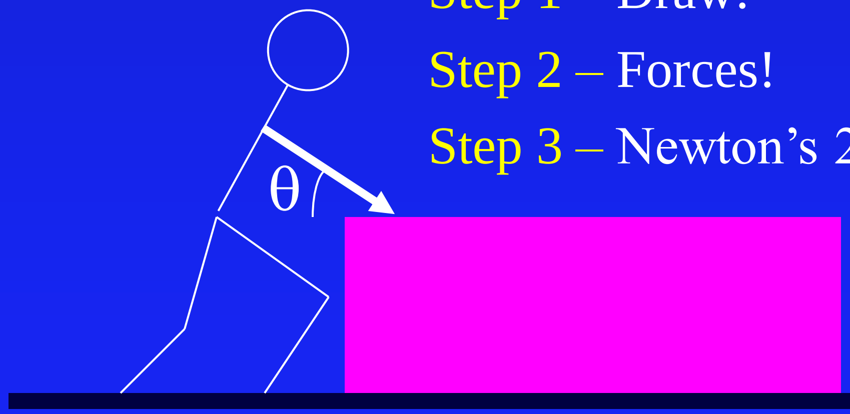
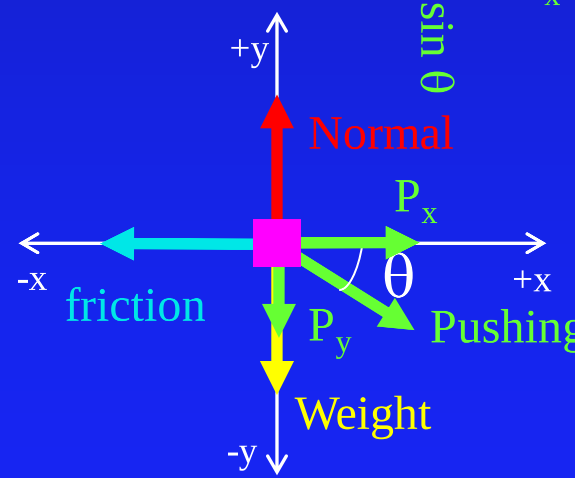




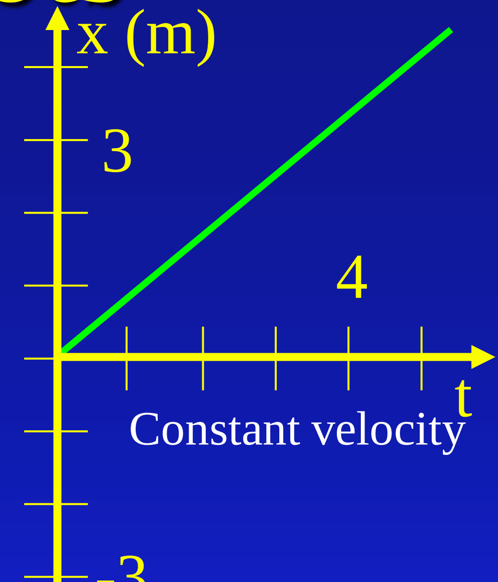
Today: An Overview

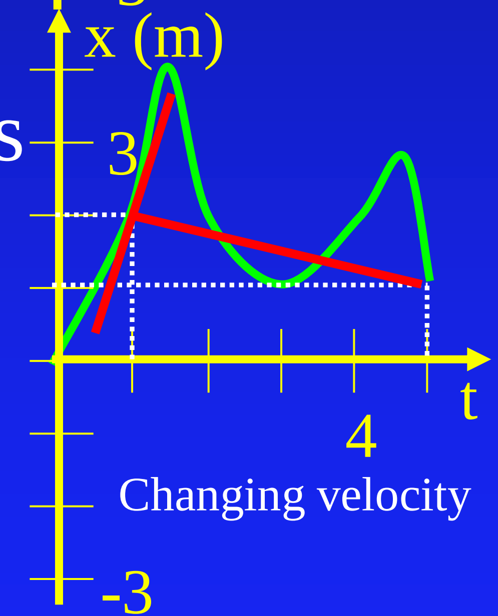
- What happens when $a \neq 0$?

- 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:

$$\Delta x = x_f - x_0$$

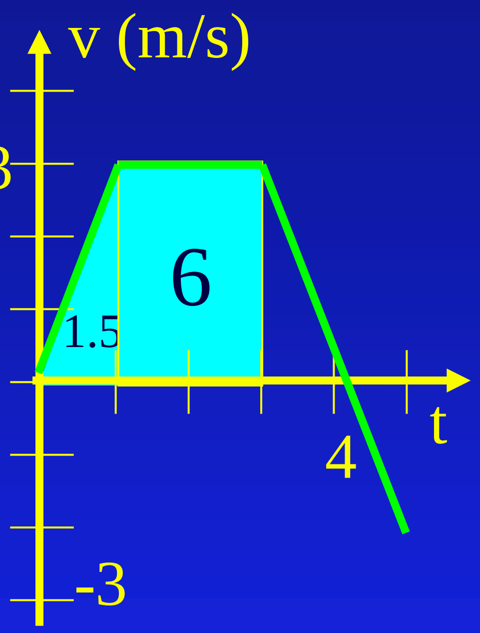
$$\Delta x = 1.0 \text{ m} - 2.0 \text{ m} = -1.0 \text{ m}$$

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

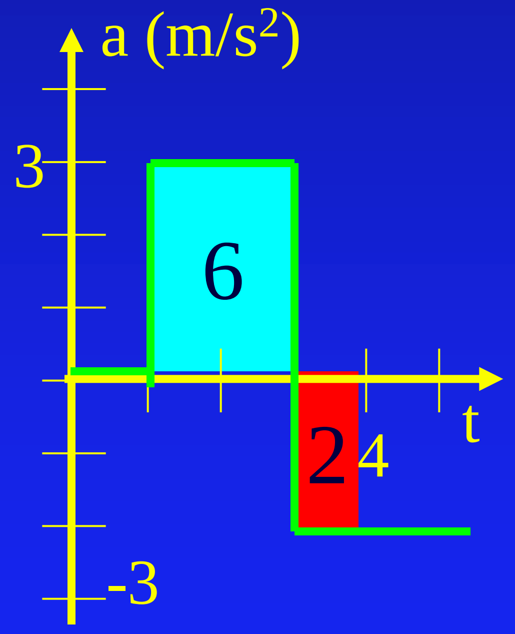
  $a = \Delta v/\Delta t \quad => \quad \Delta v = a\,\Delta t$

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

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

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

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

90% 1 - Yes

10% 2 - No

"An object can have a negative acceleration with a positive velocity if the object is slowing down. The acceleration is negative but the object will still have positive velocity."

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

97% 1 - Yes

3% 2 - No

"If I get in my car and set the cruise control at 60mph and do not speed up or slow down … then I am going [at] a velocity other than zero with an acceleration of zero."

Velocity ACT

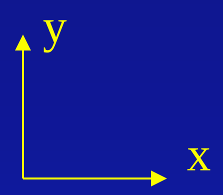
If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

A - Yes

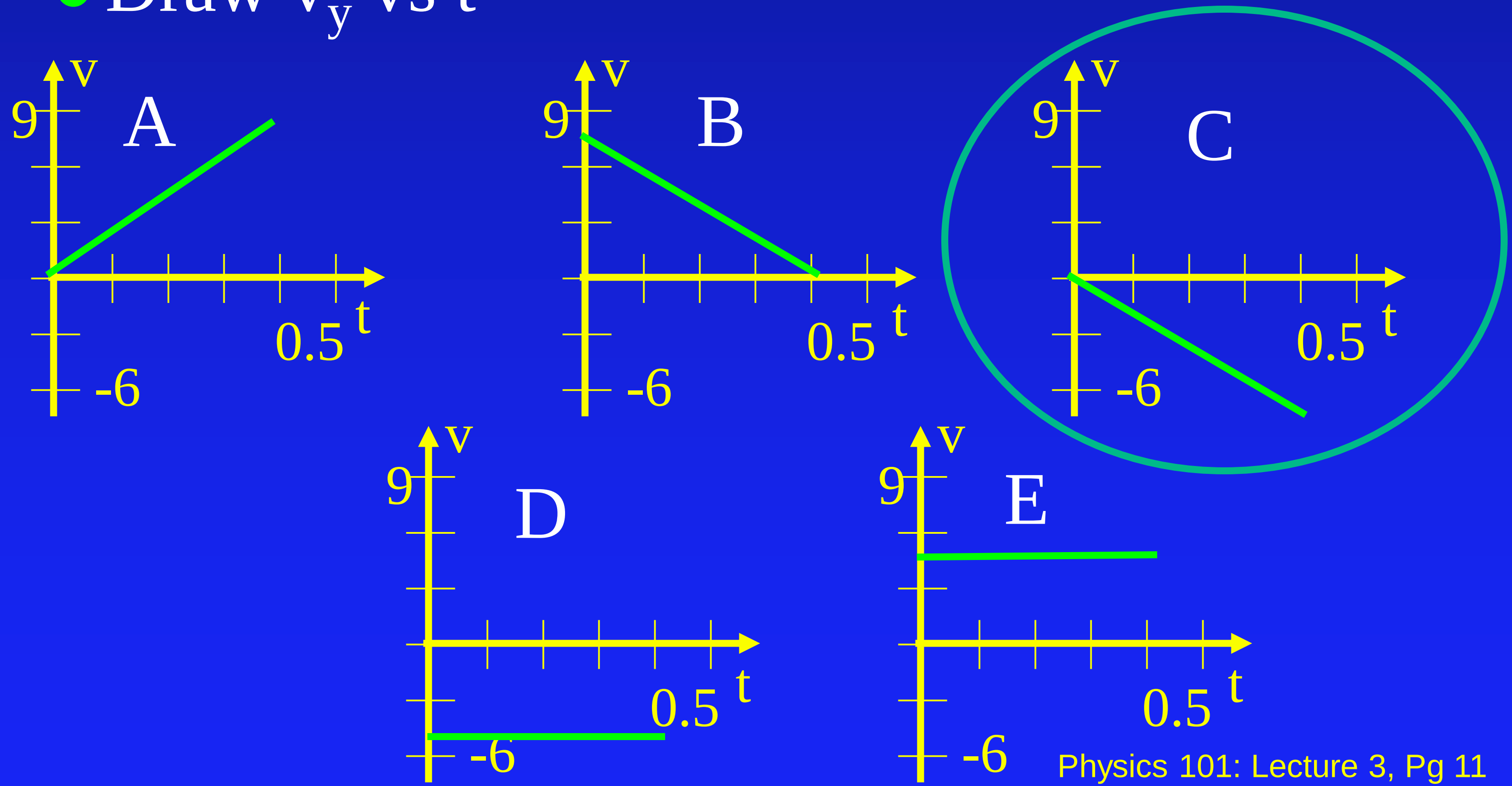
B - No

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



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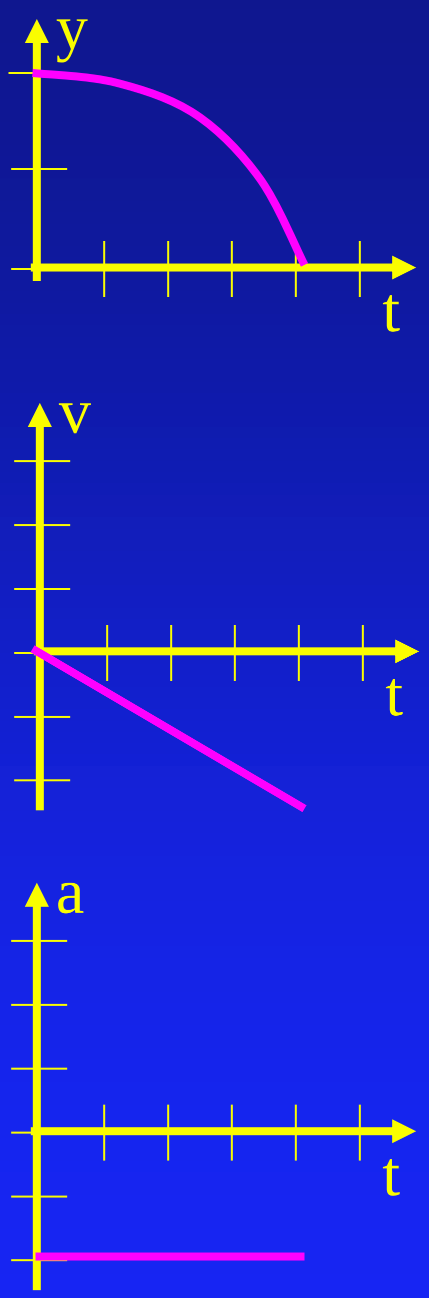
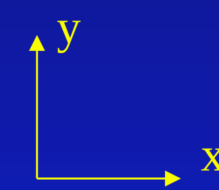


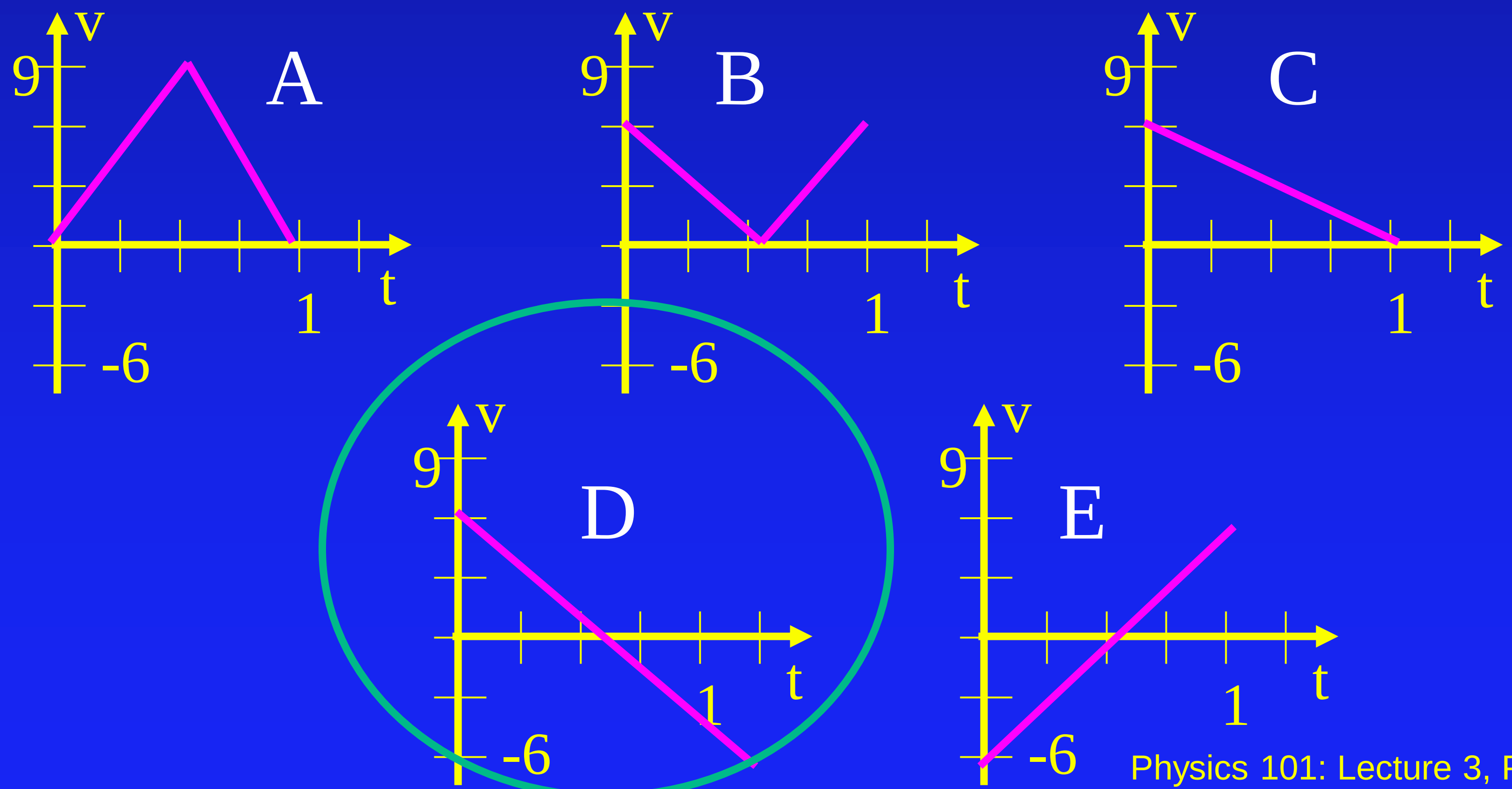
- Draw v vs t
- Draw y vs t
- Draw a vs t

Tossed Ball

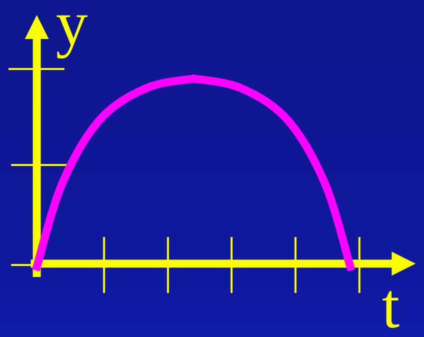
•A ball is tossed from the ground up a height of two meters above the ground. And falls back down



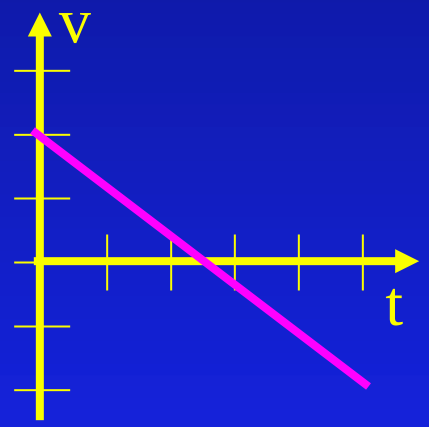
- Draw v vs t



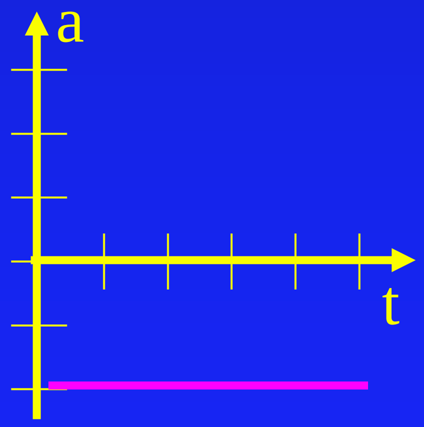
Tossed Ball



- 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.

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

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

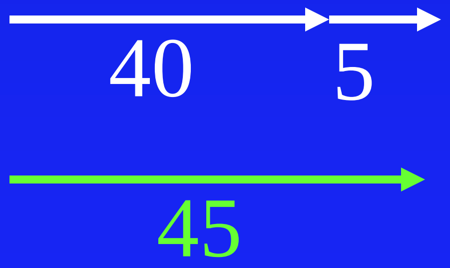
Not 0 since V_f and V_i are not the same !

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 mph N + 5 mph N = 45 mph N

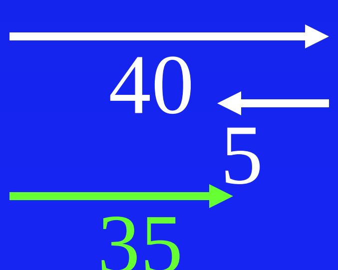


Relative Velocity

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 mph N - 5 mph N = 35 mph N

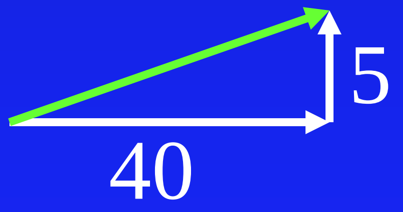


Relative Velocity

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 mph N + 5 mph W = 41 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:

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

» 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

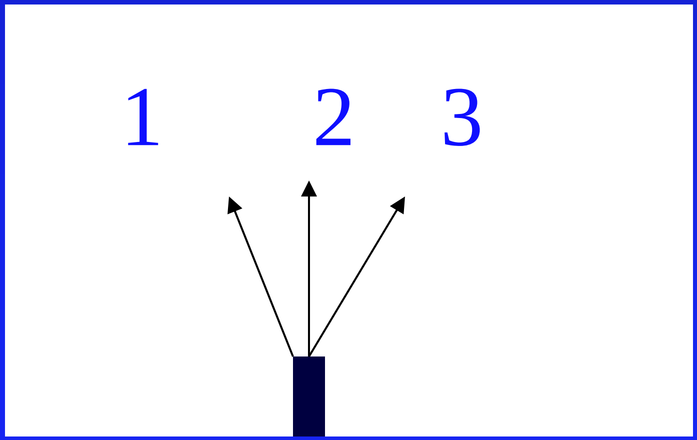
Tractor Demo 1

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



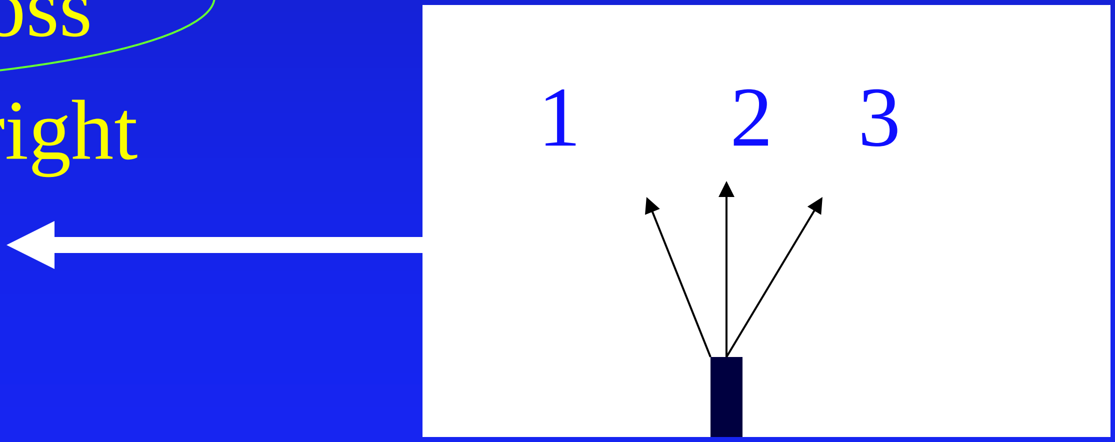
Tractor Demo (moving table)

- 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: $v_{ac} = v_{ab} + v_{bc}$