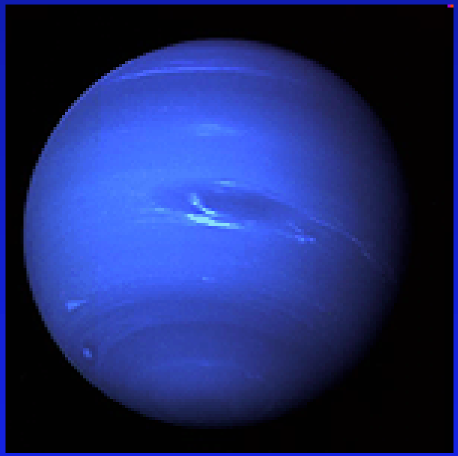
Physics 101: Lecture 04

Kinematics + Dynamics

- **Today's lecture will cover Textbook Chapter 4**

If you are new to the course,
please read the course description
on the course web page (and email policy from Lecture 1 note)!



Neptune

Review

- Kinematics : Description of Motion

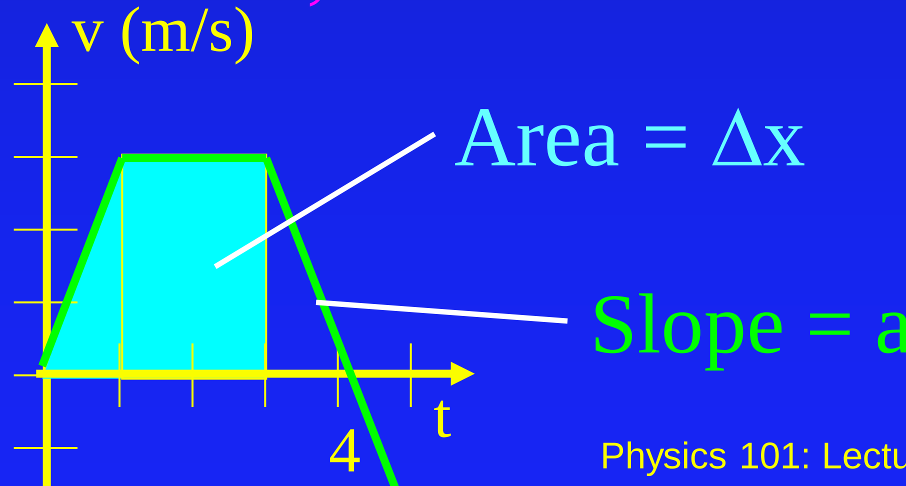
1. Displacement, Δx
2. Velocity, $v = \Delta x / \Delta t$
3. Acceleration, $a = \Delta v / \Delta t$

Slope of Δx vs. t

Slope of v vs. t

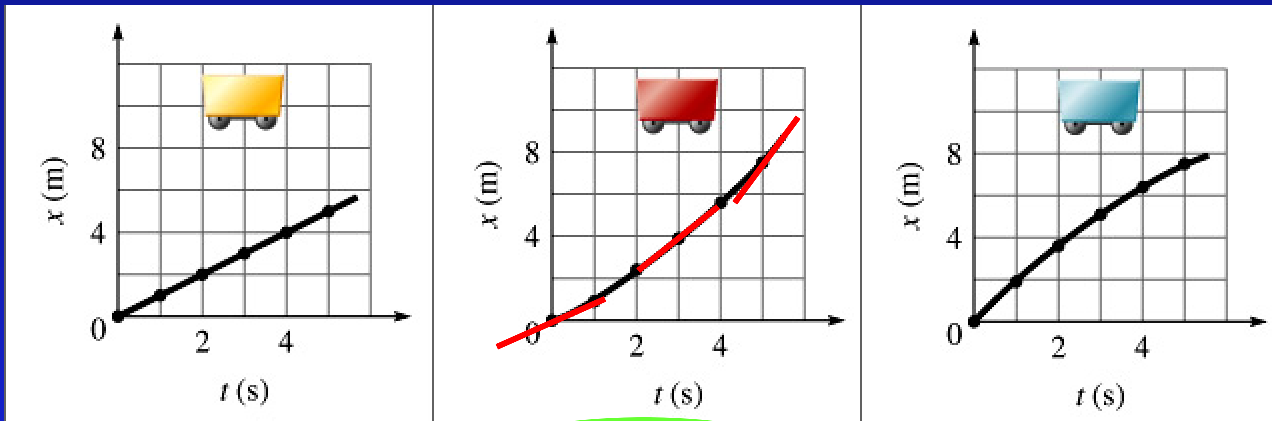
Area under v vs. t

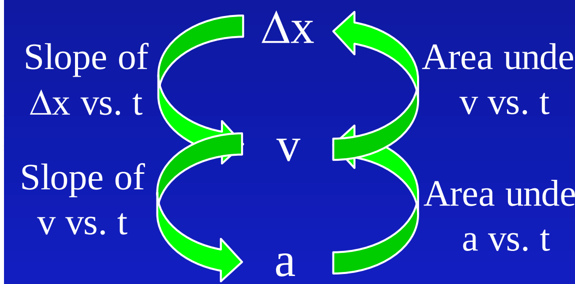
Area under a vs. t



Prelecture

…interpreting graphs…





(A) (B) (C)

- Which x vs t plot shows positive acceleration?

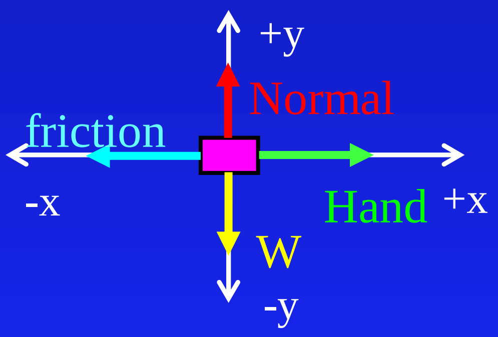
90.5% got this correct!!!!

"The x vs. t plot in option B shows a curve upwards; a line tangent to the curve (i.e. velocity) will be positive, and increases in slope as it travels along the curve."

Overview

Week 1!

Draw a FBD to determine F_{Net}

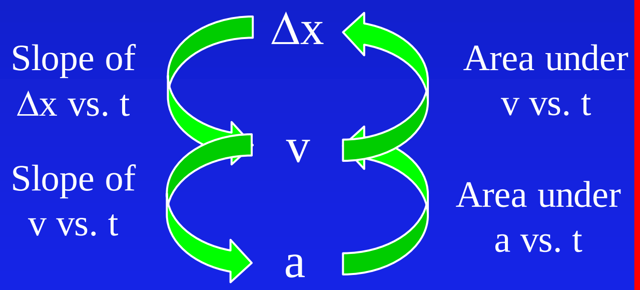


Apply Newton's 2nd Law to determine acceleration

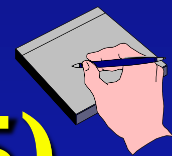
$$\vec{F}_{Net} = m\vec{a}$$

Next!

Use Kinematics to determine/describe motion of the object

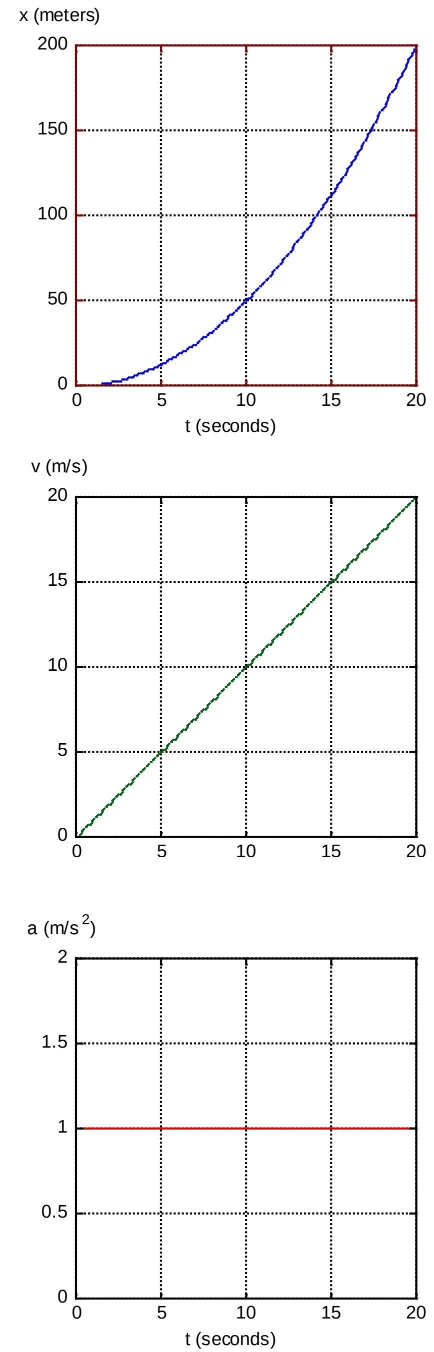


Equations for Constant Acceleration (text, page 124-125)

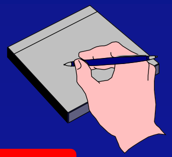


- $x = x_0 + v_0 t + 1/2\ at^2$
- $v = v_0 + at$
- $v^2 = v_0^2 + 2a(x-x_0)$

Use these equations to predict the future path and speed of an object under constant acceleration!



Kinematics Example

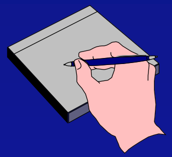


- A car is traveling 30 m/s and applies its breaks to stop after a distance of 150 m.
- How fast is the car going after it has traveled ½ the distance (75 meters) ?

A) $v < 15$ m/s   B) $v = 15$ m/s   C) $v > 15$ m/s

- $v_0 = 30$ m/s, $x - x_0 = 150$ m
- $x = x_0 + v_0 t + 1/2\, at^2$
- $v = v_0 + at$
- $\boxed{v^2 = v_0^2 + 2a(x-x_0)}$

Acceleration ACT



A car accelerates uniformly from rest ($v_0 = 0$). If it travels a distance D in time t then how far will it travel in a time 2t ?

A. D/4
B. D/2
C. D
D. 2D
E. 4D ← Correct!

$$\boxed{x - x_0 = D = 1/2\, at^2}$$

$$\boxed{v = at}$$

$$v^2 = 2a(x-x_0)$$

$$D' = 1/2\, a(2t)^2$$
$$= 4[1/2\, at^2]$$
$$= 4D$$

Follow up question: If the car has speed v at time t then what is the speed at time 2t ?

A. v/4
B. v/2
C. v
D. 2v ← Correct !
E. 4v

$$v' = a(2t)$$
$$= 2[at]$$
$$= 2v$$

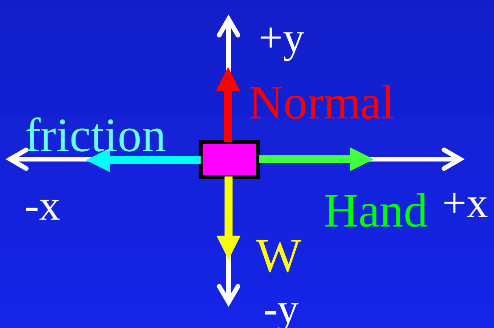
Overview

Next!

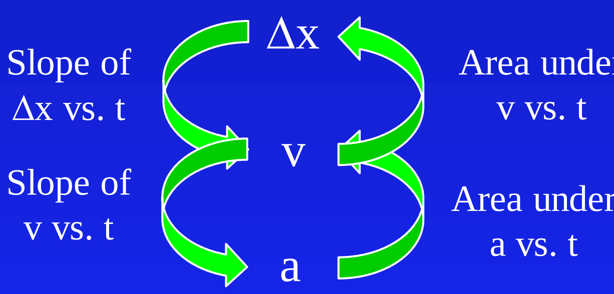
Draw a FBD to determine F_{Net}

Apply Newton's 2^{nd} Law to determine acceleration

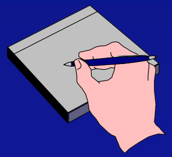
Use Kinematics to determine/describe motion of the object



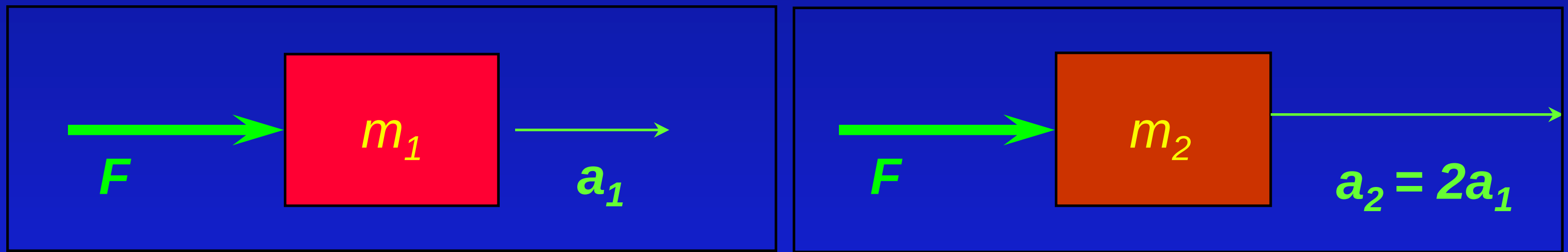
$$\vec{F}_{Net} = m\vec{a}$$



ACT



- A force F acting on a mass m_1 results in an acceleration a_1. The same force acting on a different mass m_2 results in an acceleration $a_2 = 2a_1$. What is the mass m_2?



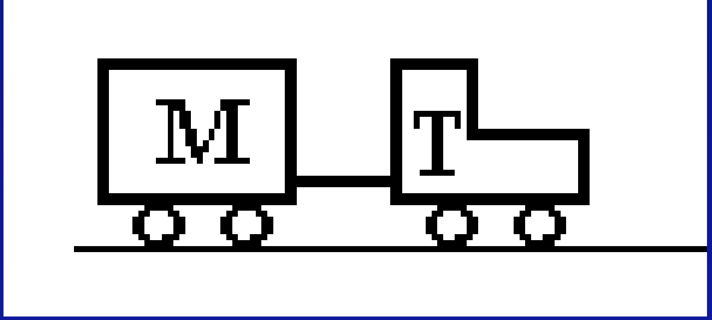
(A) $2m_1$ (B) m_1 (C) $1/2\ m_1$

- $F = ma$
- $F = m_1 a_1$

  $F = m_2 a_2 = m_2(2a_1) = 2\ m_2 a_1$

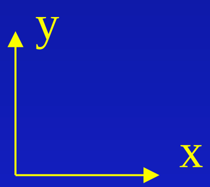
- Therefore, $m_2 = m_1/2$
- Or in words…twice the acceleration means half the mass

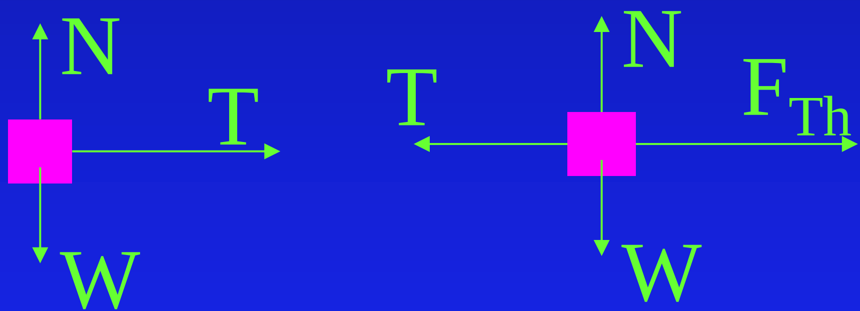
Example:



A tractor T (m=300Kg) is pulling a trailer M (m=400Kg). It starts from rest and pulls with constant force such that there is a positive acceleration of 1.5 m/s^2. Calculate the horizontal thrust force of the tractor.

$$\boxed{F_{Th} = 1050\text{ N}}$$





Tractor – x direction

$F_{Net} = ma$

$F_{Th} - T = m_{tractor}a$

$F_{Th} = T + m_{tractor}a$

Trailer – x direction

$F_{Net} = ma$

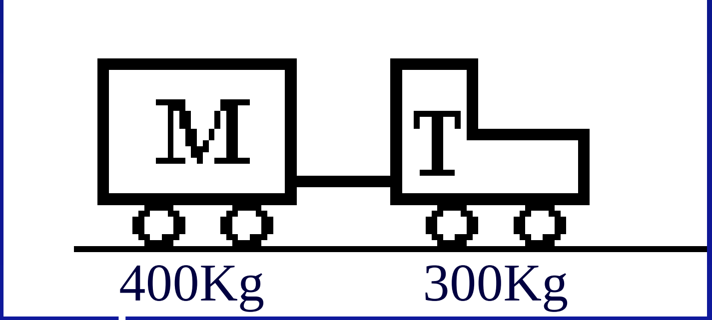
$T = m_{trailer}a$

Combine:

$F_{Th} = m_{trailer}a + m_{tractor}a$

$F_{Th} = (m_{trailer} + m_{tractor})\, a$

Net Force ACT



Compare $F_{tractor}$ the net force on the tractor, with $F_{trailer}$ the net force on the trailer from the previous problem.

A) $F_{tractor} > F_{trailor}$

B) $F_{tractor} = F_{trailor}$

C) $F_{tractor} < F_{trailor}$

$$F_{Net} = m\ a$$

$$F_{tractor} = m_{tractor}\ a$$
$$= (300\ \text{kg})\ (1.5\ \text{m/s}^2)$$
$$= 450\ \text{N}$$

$$F_{trailer} = m_{trailer}\ a$$
$$= (400\ \text{kg})\ (1.5\ \text{m/s2})$$
$$= 600\ \text{N}$$

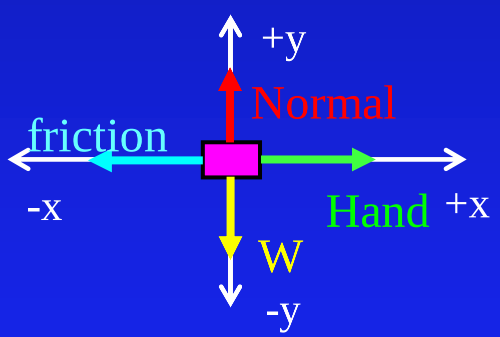
Overview

Next!

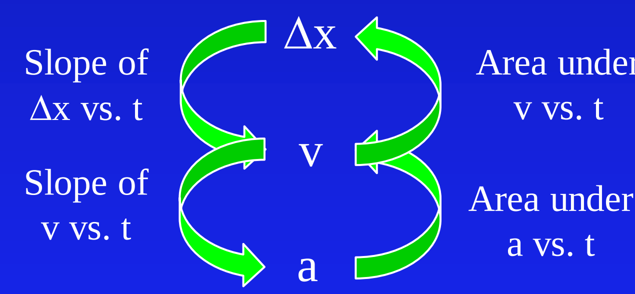
Draw a FBD to determine F_{Net}

Apply Newton's 2nd Law to determine acceleration

Use Kinematics to determine/describe motion of the object



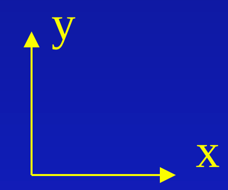
$$\vec{F}_{Net} = m\vec{a}$$



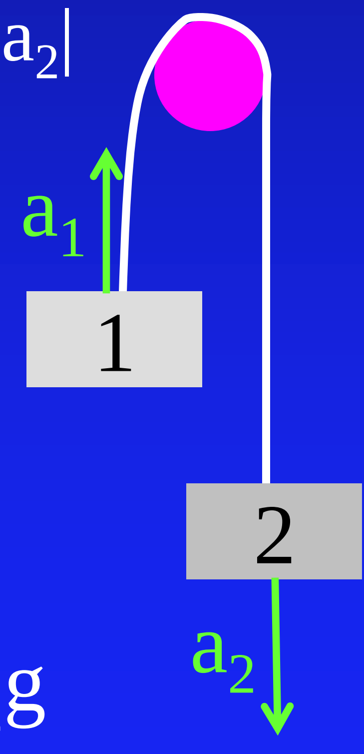
Pulley Example

- Two boxes are connected by a string over a frictionless pulley. Box 1 has mass 1.5 kg, box 2 has a mass of 2.5 kg. Box 2 starts from rest 0.8 meters above the table, how long does it take to hit the table?

•Compare the acceleration of boxes 1 and 2



A) $|a_1| > |a_2|$ B) $|a_1| = |a_2|$ C) $|a_1| < |a_2|$



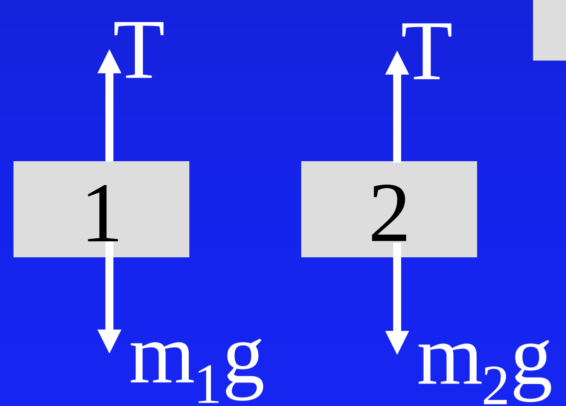
1) $T - m_1 g = m_1 a_1$

2) $T - m_2 g = m_2 a_2 = -m_2 a_1$

2) $T = m_2 g - m_2 a_1$

1) $m_2 g - m_2 a_1 - m_1 g = m_1 a_1$

$a_1 = (m_2 - m_1)g / (m_1+m_2)$



Pulley Example

- Two boxes are connected by a string over a frictionless pulley. Box 1 has mass 1.5 kg, box 2 has a mass of 2.5 kg. Box 2 starts from rest 0.8 meters above the table, $\boxed{\text{how long does it take to hit the table?}}$

- $v_0 = 0$ m/s, $\Delta x = 0.8$ m, $t = ?$

$a_1 = (m_2 - m_1)g / (m_1+m_2)$

$a_1 = 2.45 \text{ m/s}^2$

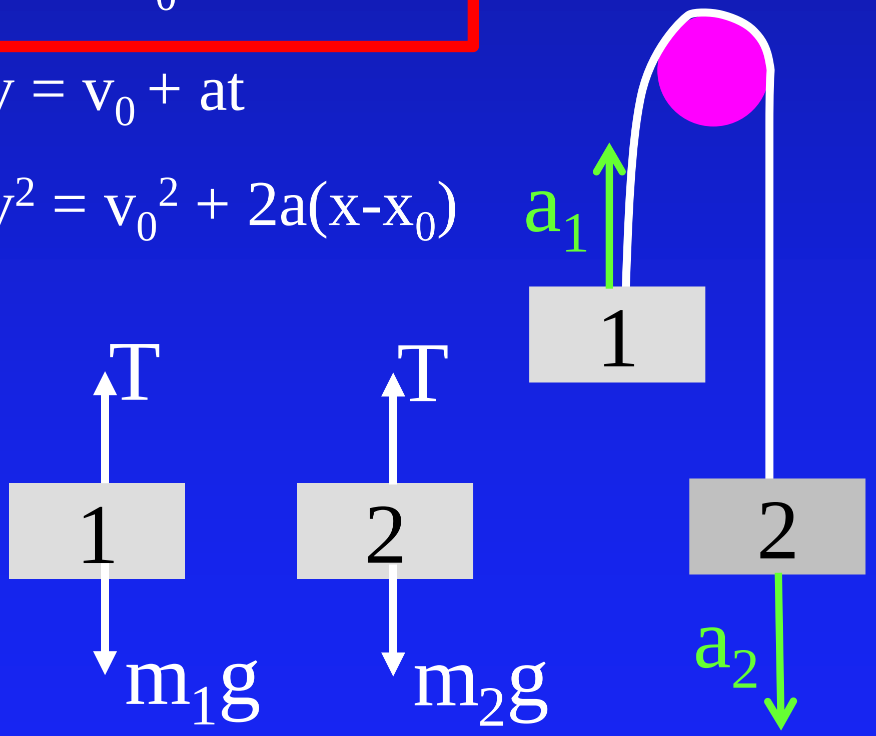
$\Delta x = v_0 t + ½ a t^2$

$\Delta x = ½ a t^2$

$t = \text{sqrt}(2 \Delta x/a)$

$t = 0.81$ seconds

- $\boxed{\Delta x = v_0 t + 1/2\, at^2}$
- $v = v_0 + at$
- $v^2 = v_0^2 + 2a(x-x_0)$



Summary of Concepts

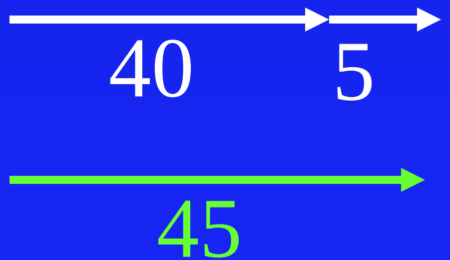
- Constant Acceleration
  - $x = x_0 + v_0 t + 1/2\ at^2$
  - $v = v_0 + at$
  - $v^2 = v_0^2 + 2a(x-x_0)$
- $F = m\ a$
  - Draw Free Body Diagram
  - Write down equations
  - Solve
- Next time: textbook section 4.3, 4.5

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

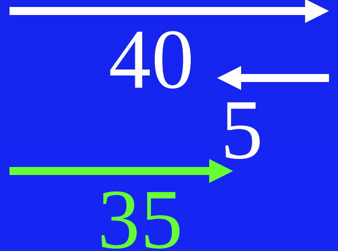
You are on a train traveling 40 mph North. If you walk 5 mph toward the rear of the train, what is your speed relative to the ground?

A) 45 mph

B) 40 mph

C) 35 mph

40 mph N - 5 mph N = 35 mph N

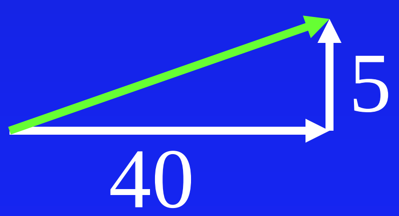


Relative Velocity

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

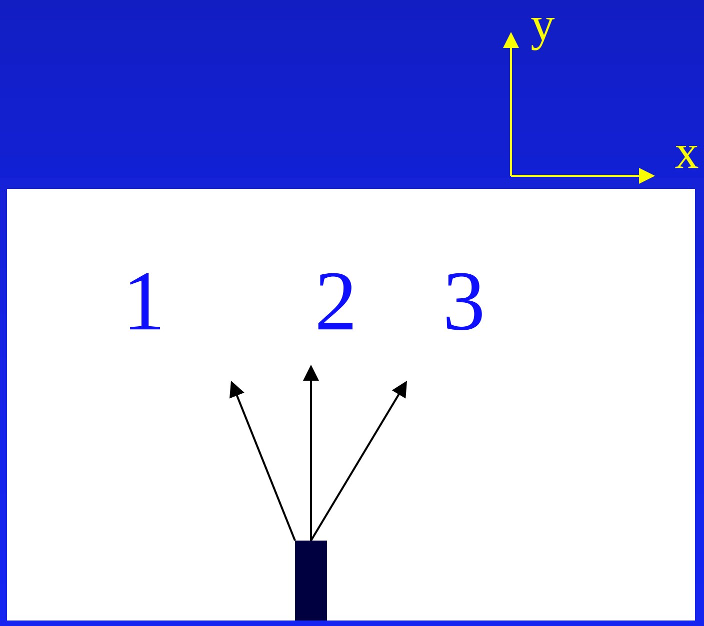
Tractor Demo 1

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



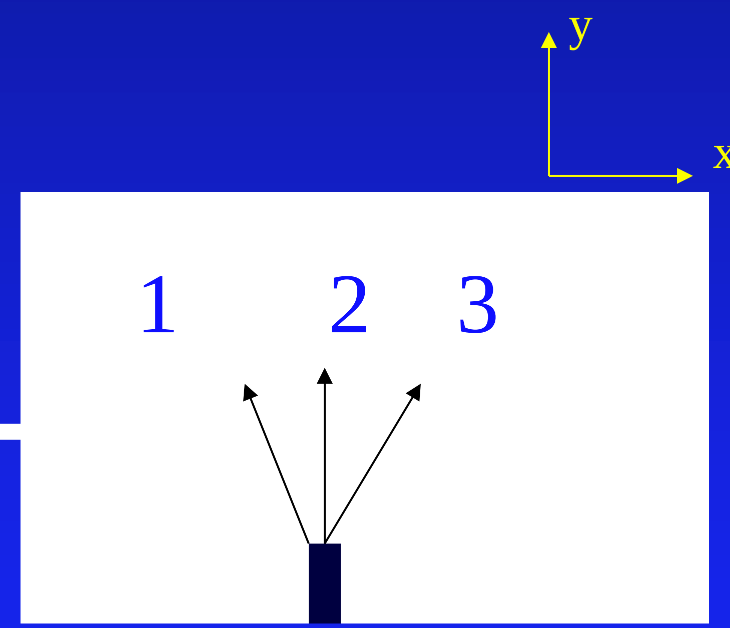
Tractor Demo (moving table)

- 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



- Motion in y is independent of x!