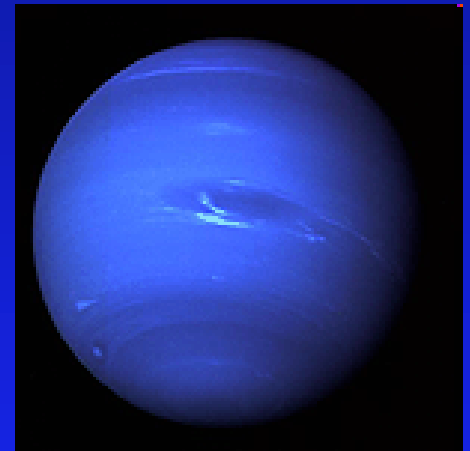


Physics 101: Lecture 04

Kinematics + Dynamics

- Today's lecture will cover
Textbook Chapter 4

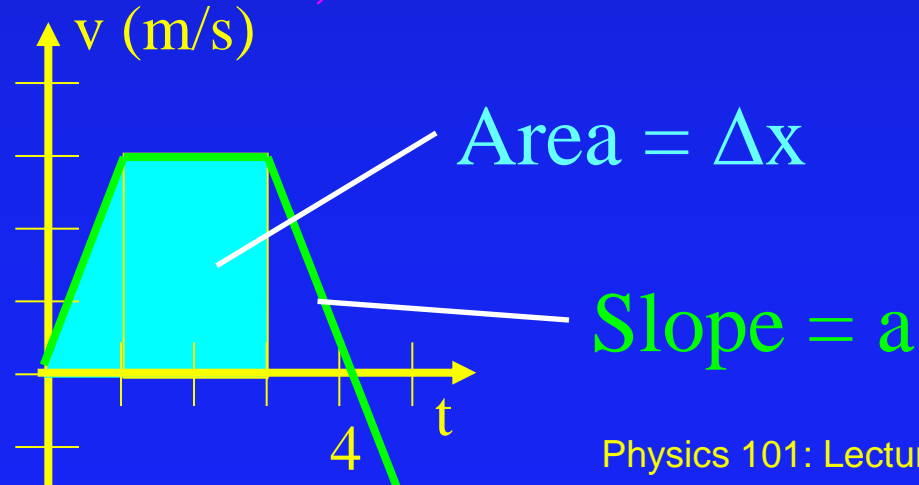
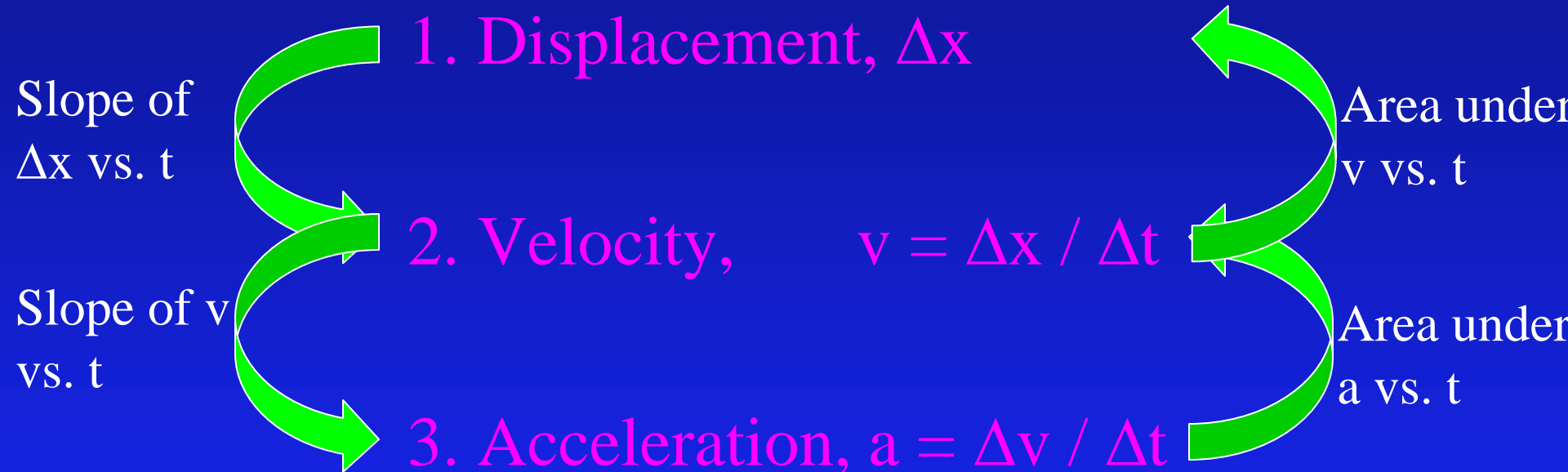
If you are new to the course,
please read the course description
on the course web page.



Neptune

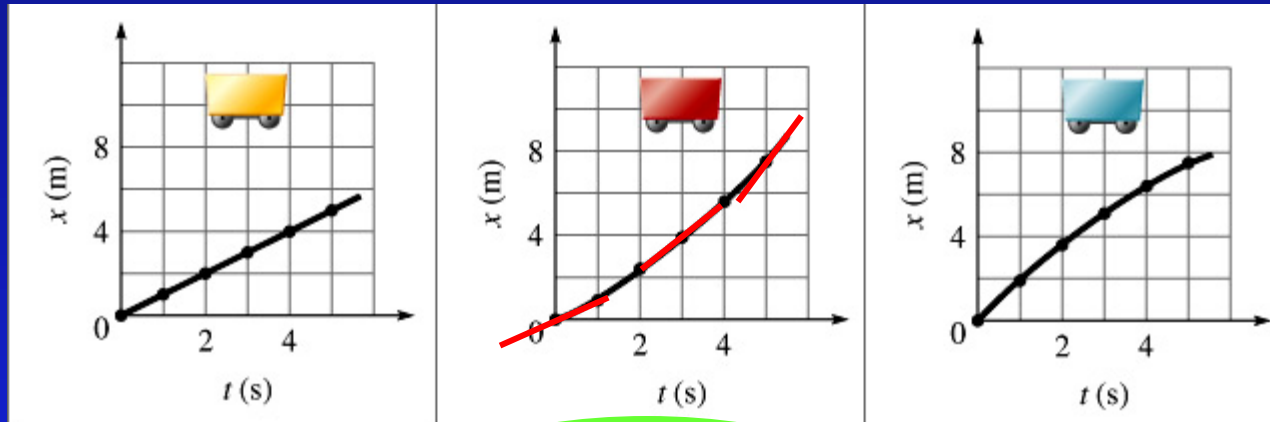
Review

- Kinematics : Description of Motion



Checkpoint

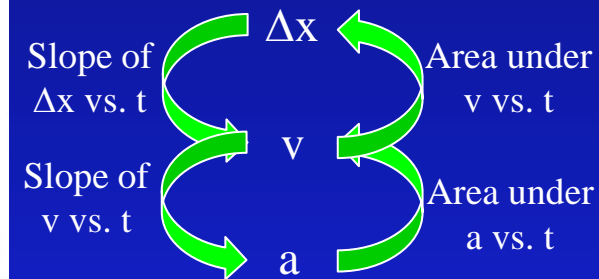
...interpreting graphs...



(A)

(B)

(C)

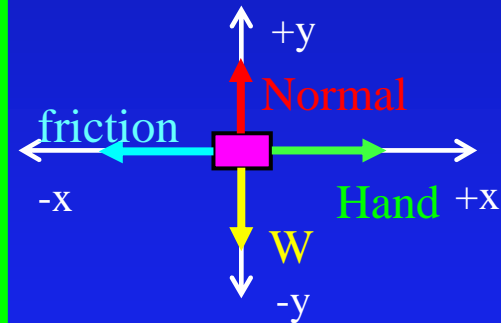


- Which x vs t plot shows positive acceleration?

Overview

Week 1!

Draw a FBD to determine F_{Net}

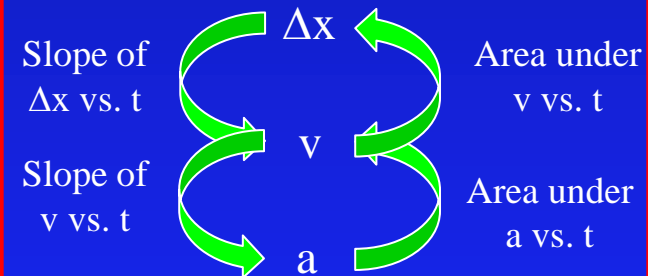


Apply Newton's 2nd Law to determine acceleration

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

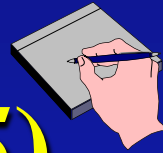
Next!

Use Kinematics to determine/describe motion of the object



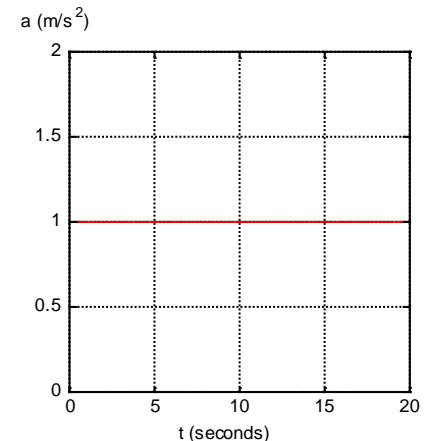
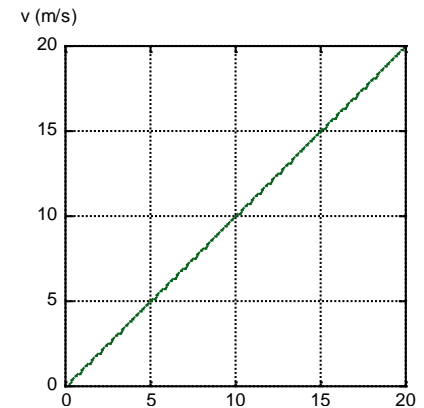
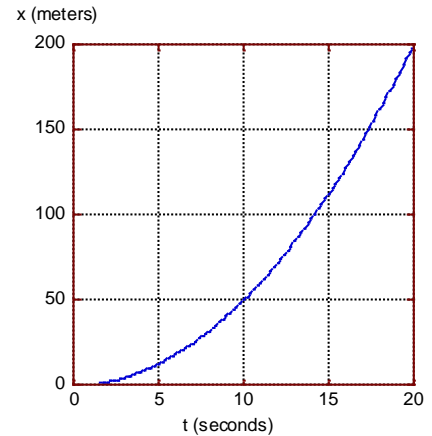
Equations for Constant Acceleration

(text, page 124-125)

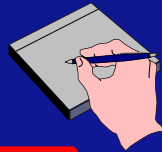


- $x = x_0 + v_0 t + \frac{1}{2} a t^2$
- $v = v_0 + a t$
- $v^2 = v_0^2 + 2a(x - x_0)$

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 $\frac{1}{2}$ the distance (75 meters) ?

A) $v < 15$ m/s

B) $v = 15$ m/s

C) $v > 15$ m/s

- $x = x_0 + v_0 t + \frac{1}{2} a t^2$

- $v = v_0 + a t$

- $v^2 = v_0^2 + 2a(x - x_0)$

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!

$$x - x_0 = \frac{1}{2} at^2$$

$$v = at$$

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

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. $4v$

Overview

Next!

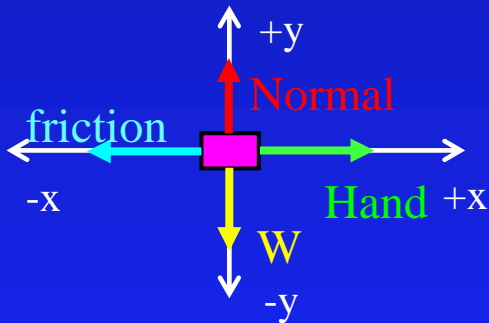
Draw a FBD to determine F_{Net}



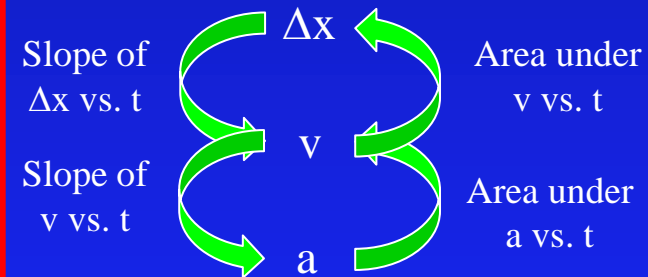
Apply Newton's 2nd Law to determine acceleration



Use Kinematics to determine/describe motion of the object



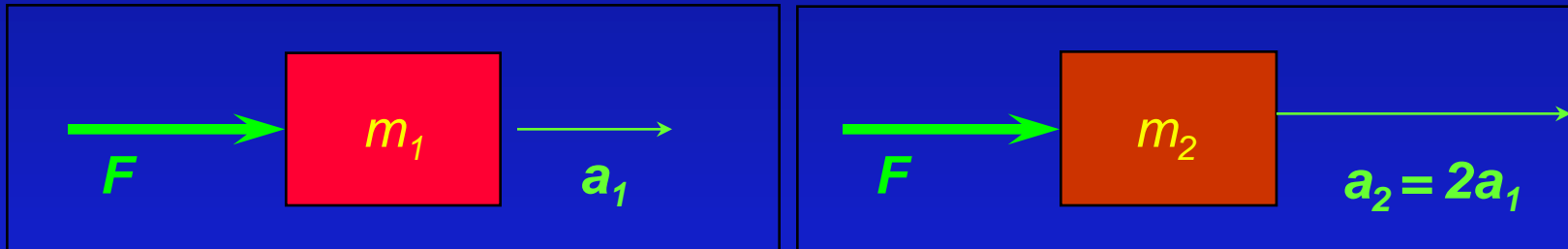
$$\vec{F}_{\text{Net}} = m\vec{a}$$



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) $2m_1$

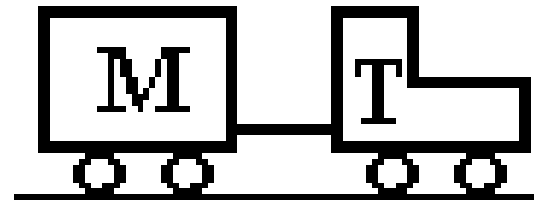
(B) m_1

(C) $1/2 m_1$

- $F=ma$
- $F= m_1a_1 = m_2a_2 = m_2(2a_1) = 2 m_2a_1$
- Therefore, $m_2 = m_1/2$
- Or in words...twice the acceleration means half the mass



Example:



A tractor T ($m=300\text{Kg}$) is pulling a trailer M ($m=400\text{Kg}$). 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 on the tractor due to the ground.

Tractor – x direction

$$F_{\text{Net}} = ma$$

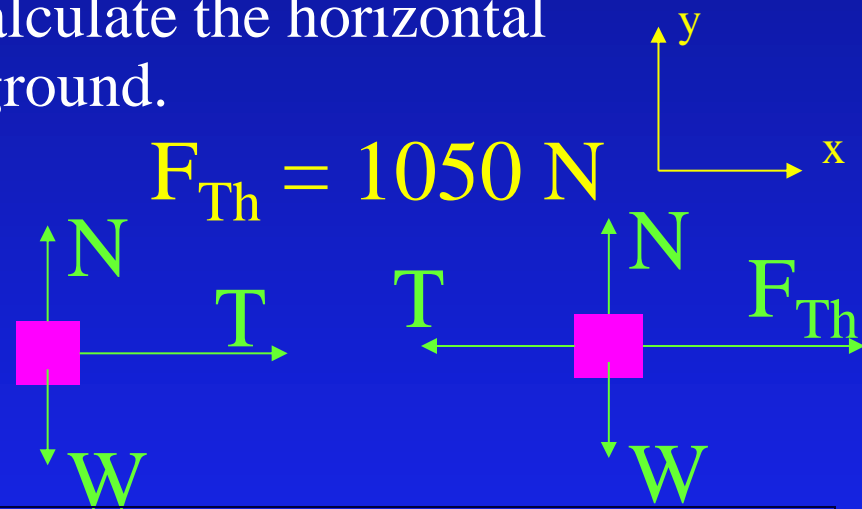
$$F_{\text{Th}} - T = m_{\text{tractor}}a$$

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

Trailer – x direction

$$F_{\text{Net}} = ma$$

$$T = m_{\text{trailer}}a$$

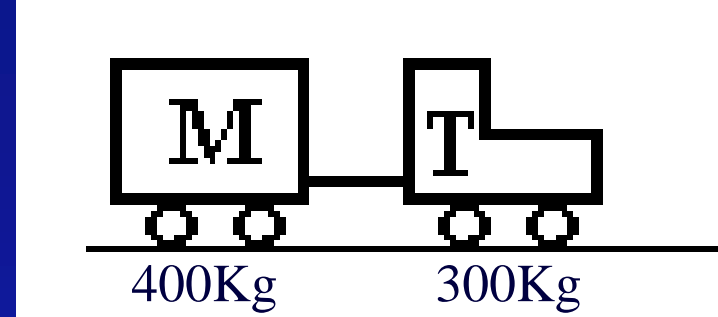


Combine:

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

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

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) $F_{\text{tractor}} > F_{\text{trailer}}$

B) $F_{\text{tractor}} = F_{\text{trailer}}$

C) $F_{\text{tractor}} < F_{\text{trailer}}$

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

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

$$\begin{aligned} F_{\text{trailer}} &= m_{\text{trailer}} a \\ &= (400 \text{ kg}) (1.5 \text{ m/s}^2) \\ &= 600 \text{ N} \end{aligned}$$

Overview

Next!

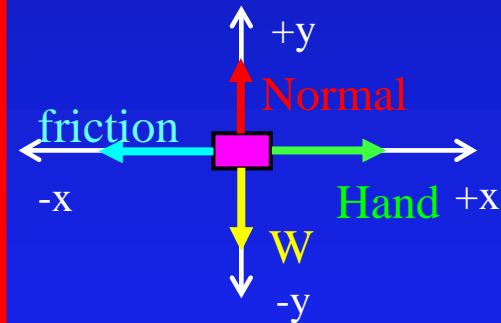
Draw a FBD to determine F_{Net}



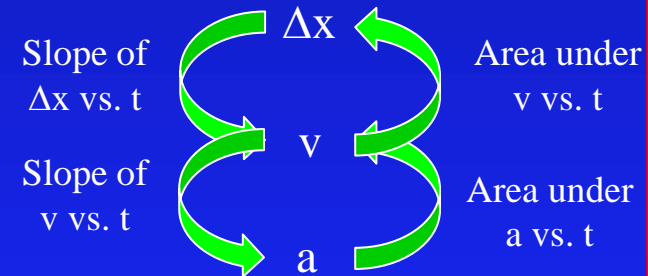
Apply Newton's 2nd Law to determine acceleration



Use Kinematics to determine/describe motion of the object



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



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) $|a_1| < |a_2|$

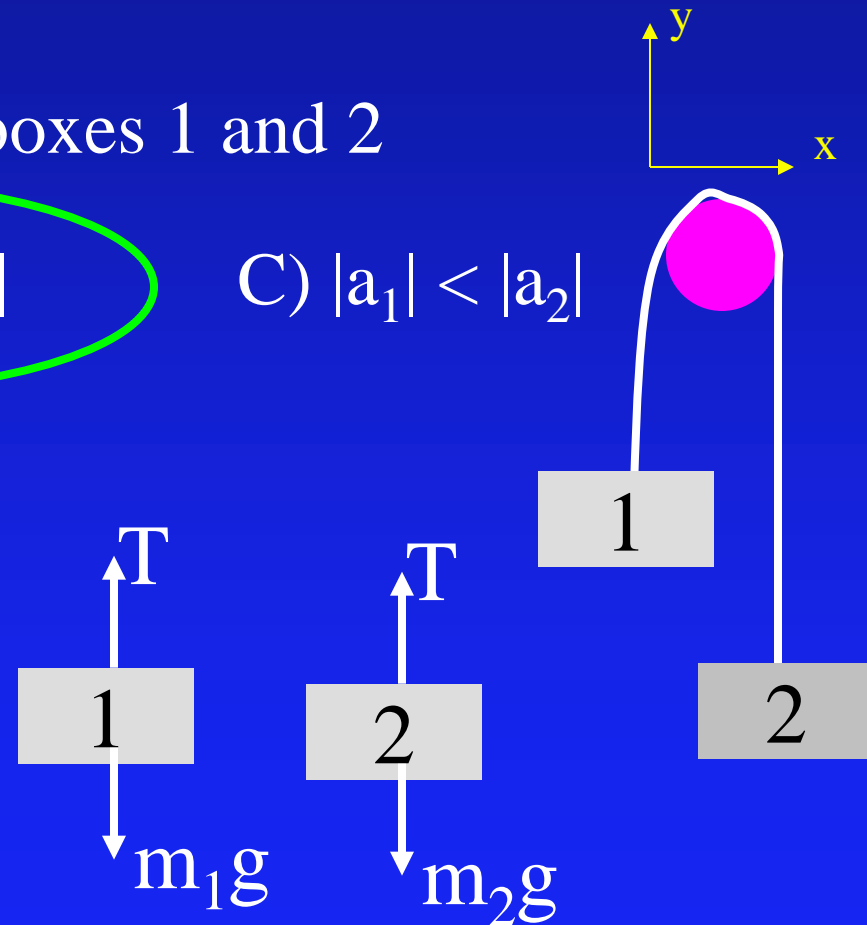
1) $T - m_1 g = m_1 a_1$

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

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, 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) $|a_1| < |a_2|$

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

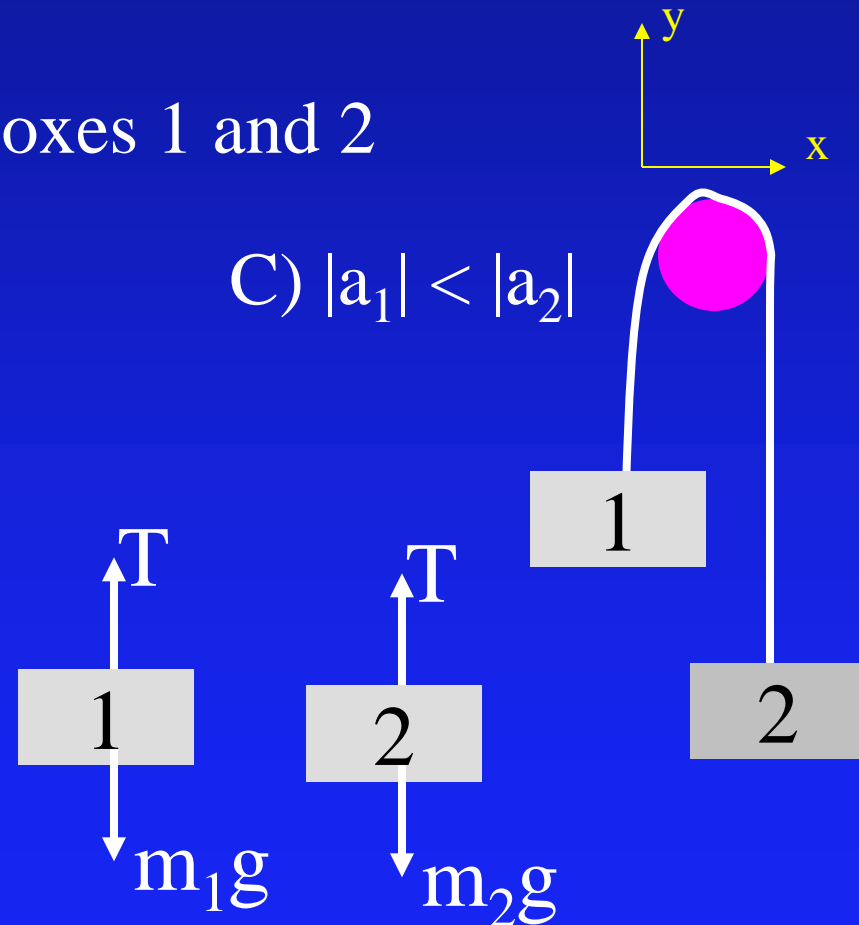
$$a = 2.45 \text{ m/s}^2$$

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$\Delta x = \frac{1}{2} a t^2$$

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

$$t = 0.81 \text{ seconds}$$



Summary of Concepts

- Constant Acceleration

- $x = x_0 + v_0 t + \frac{1}{2} a t^2$

- $v = v_0 + a t$

- $v^2 = v_0^2 + 2a(x - x_0)$

- $F = m a$

- Draw Free Body Diagram

- Write down equations

- Solve

- Next time: textbook section 4.3, 4.5

Relative Velocity (first pass)

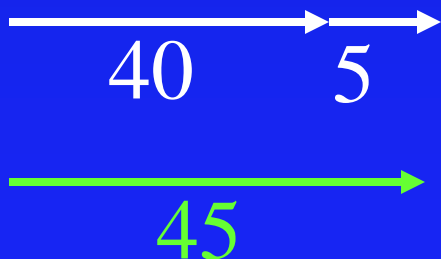
You are on a train traveling 40 mph North. If you walk 5 mph toward the front of the train, what is your speed relative to the ground?

A) 45 mph

B) 40 mph

C) 35 mph

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



Relative Velocity

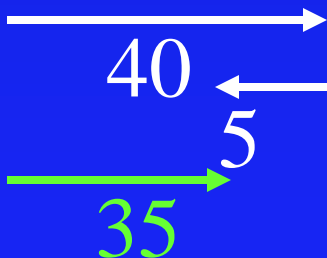
You are on a train traveling 40 mph North. If you walk 5 mph toward the rear of the train, what is your speed relative to the ground?

A) 45 mph

B) 40 mph

C) 35 mph

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



Relative Velocity

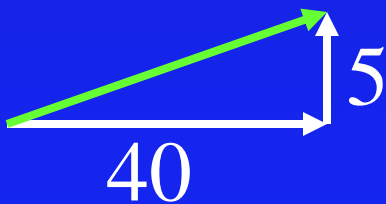
You are on a train traveling 40 mph North. If you walk 5 mph sideways across the car, what is your speed relative to the ground?

A) < 40 mph

B) 40 mph

C) > 40 mph

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



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

Relative Velocity

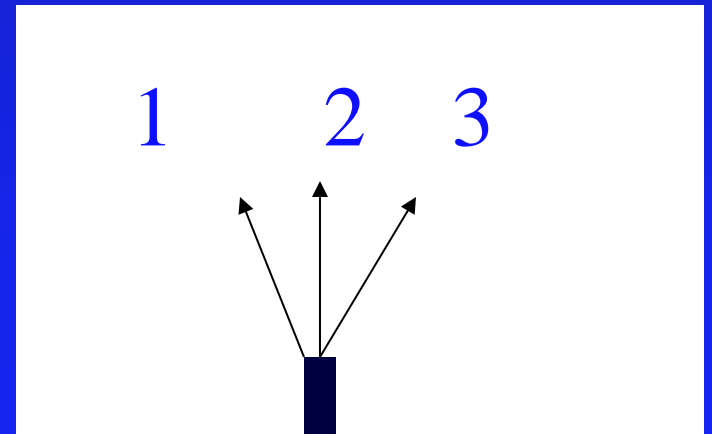
- Sometimes your velocity is known relative to a reference frame that is moving relative to the earth.
 - ➔ Example 1: A person moving relative to a train, which is moving relative to the ground.
 - ➔ Example 2: a plane moving relative to air, which is then moving relative to the ground.
- These velocities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

