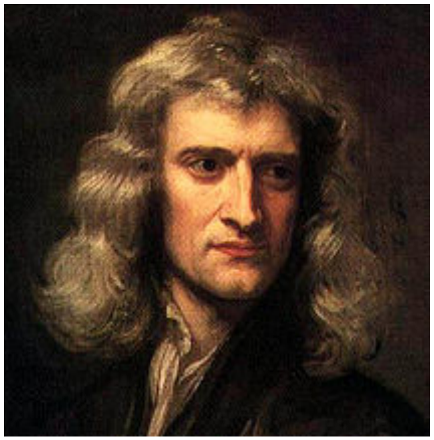
University Physics 226N/231N
Old Dominion University



More on Newton and Forces
And Midterm Notes

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Happy Birthday to F. Scott Fitzgerald, Mean Joe Greene, Phil Hartman, and Janet Weiss!

Happy Buy Nothing Day, Cherries Jubilee Day, and National Punctuation Day!!!!!!!!!!!!

Midterm Misconceptions I

- I'll hopefully have all the midterms graded by Wednesday
  - Overall grades seem reasonable, with a wide range
- There are some consistent errors
  - Some border on misconceptions so they're worth quick review
- When up is positive, the acceleration of gravity is $g=-9.8\ \mathrm{m/s^2}$
  - Would often see $x - x_0 = v_0 t + (1/2) a t^2$ followed by a substitution of $a = 9.8\ \mathrm{m/s^2}$… Consistency of signs matters!
- Write units with *all* numbers that have them
  - Even numbers where you're figuring out a calculation
  - This will *save* you effort in the long run

Midterm Misconceptions II

Not so good

$$y - y_0 = v_{y0} t + (1/2) a t^2$$
$$4.0 = (2.2)(1.8) + (1/2) a (1.8)^2$$

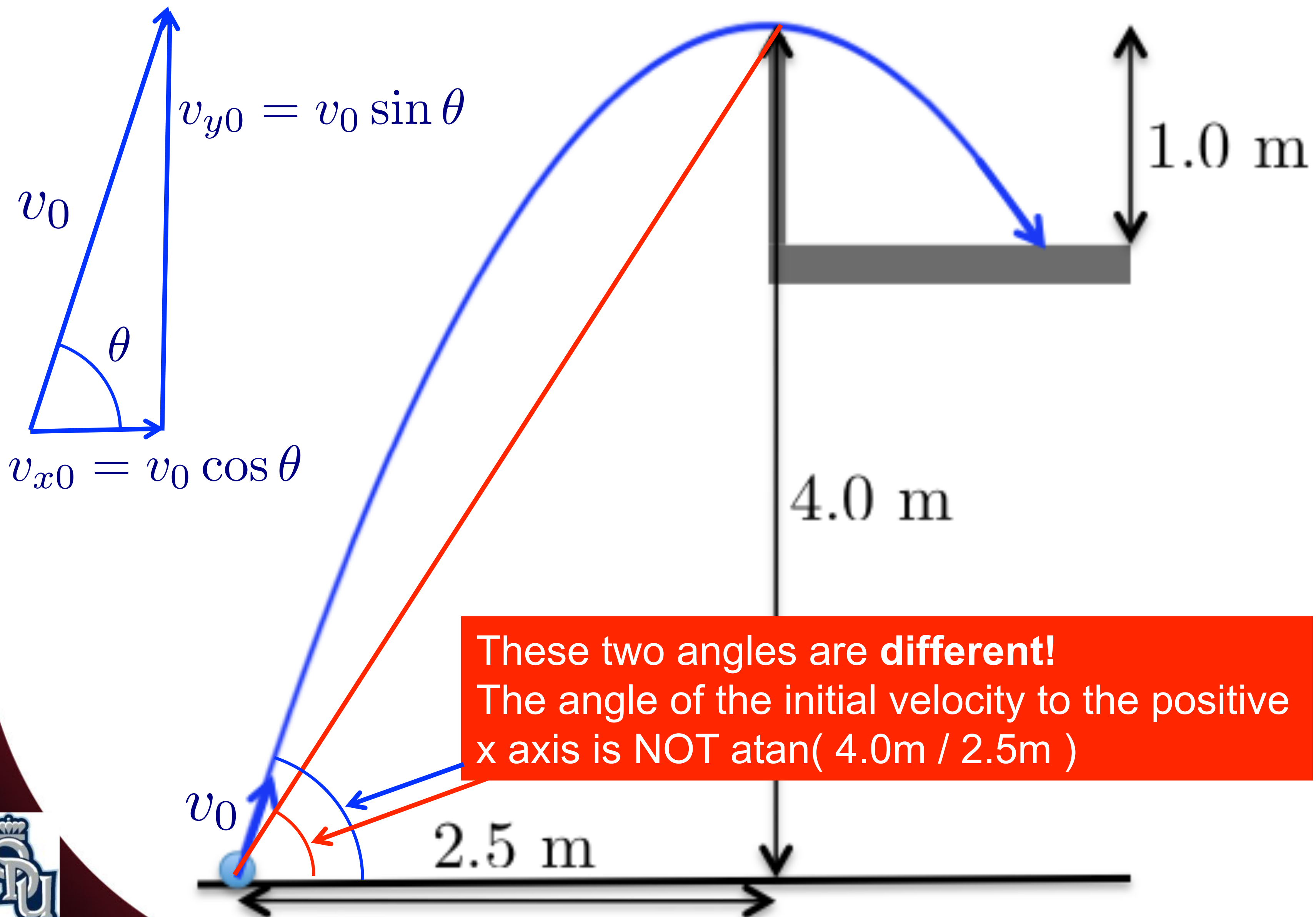
Better

$$y - y_0 = v_{y0} t + (1/2) a t^2$$
$$4.0\ \mathrm{m} = (2.2\ \mathrm{mi/hr})(1.8\ \mathrm{s}) + (1/2) a (1.8\ \mathrm{s})^2$$

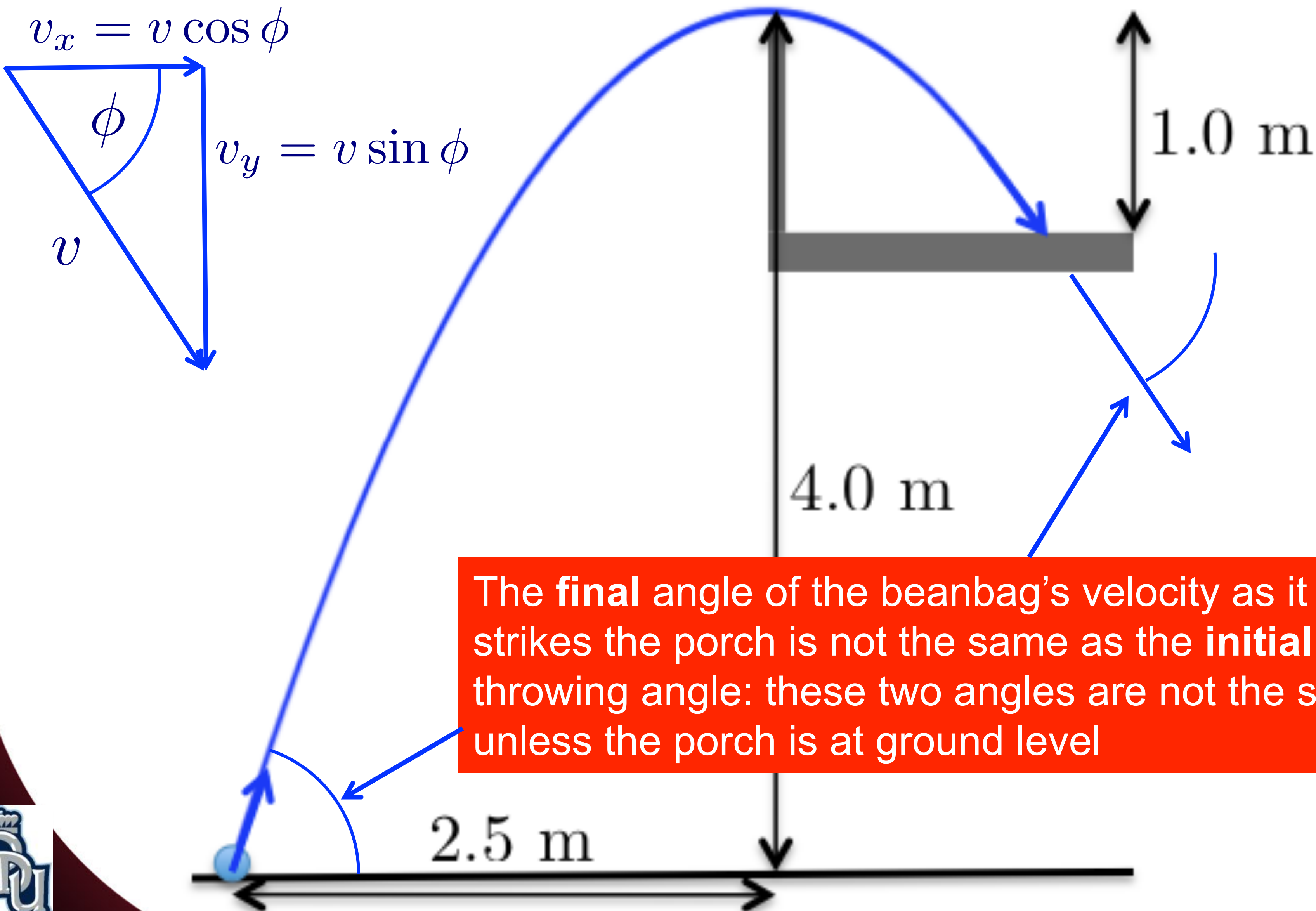
- With units it's always clear…
  - what conversions need to be done (if any), including mm/km etc
  - what the calculation's final units are
  - which numbers are pure numbers (e.g. ½) and which are measurements

  - This gets even more important (and helps eliminate confusion) when working with angles (degrees vs radians)

Midterm Misconceptions III: Problem 5 Geometry



Midterm Misconceptions IV: Problem 5 Angles



The **final** angle of the beanbag's velocity as it strikes the porch is not the same as the **initial** throwing angle: these two angles are not the same unless the porch is at ground level

Galileo and Newton

- We can resolve the inconsistencies!
- **Forces do not cause velocity**
- **Forces instead cause changes in velocity**
  - Hey, wait, this is just acceleration
- Yes, **forces are vectors** that are directly related to **acceleration**

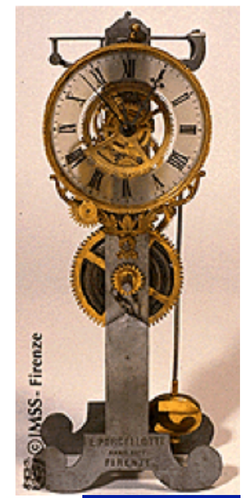
$$\boxed{\vec{F}_{\mathrm{net}} = m\vec{a}}$$

Net Force

Mass or Inertia

Acceleration

Galileo



Clock!

Jefferson Lab

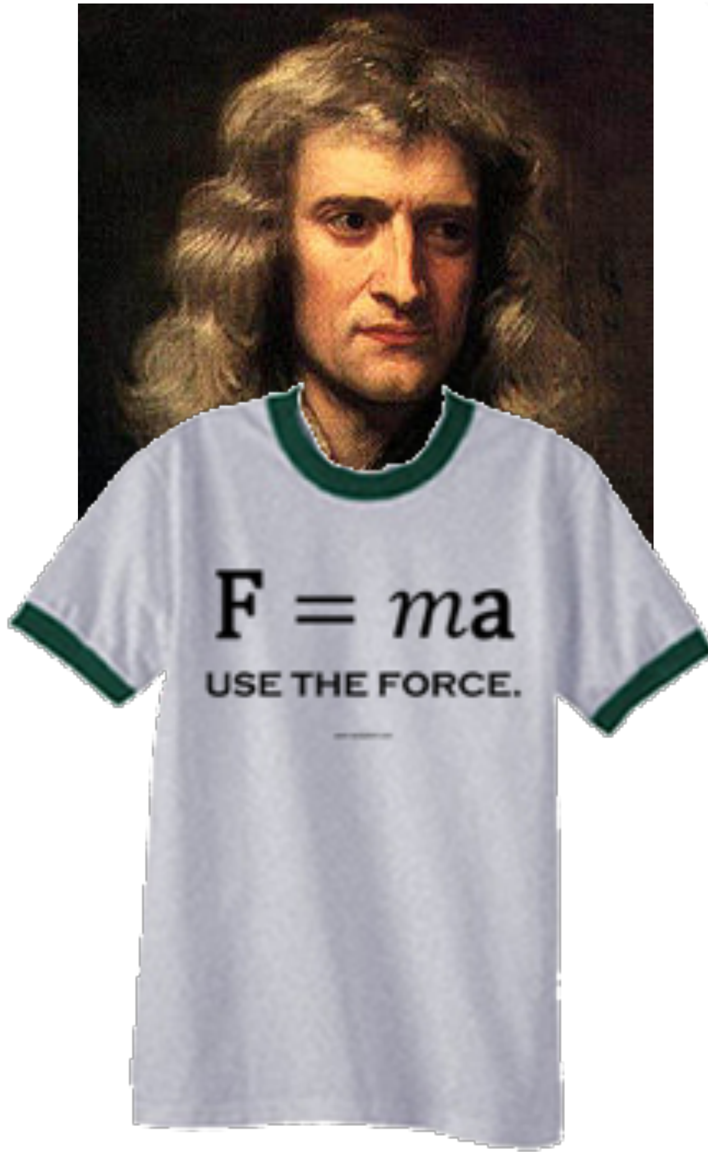
Use the Force, Newt!

- Newton's three "laws" of motion (1687)
- Newton's First Law

  A body in uniform motion remains in uniform motion, and a body at rest remains at rest, unless acted on by a nonzero net force.

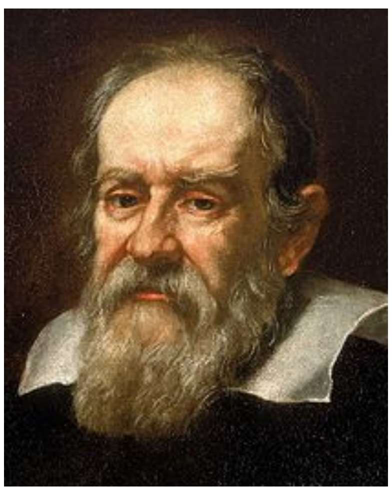
- Newton's Second Law
  - This was basically $\vec{F}_{\text{net}} = m\vec{a}$
- Newton's Third Law

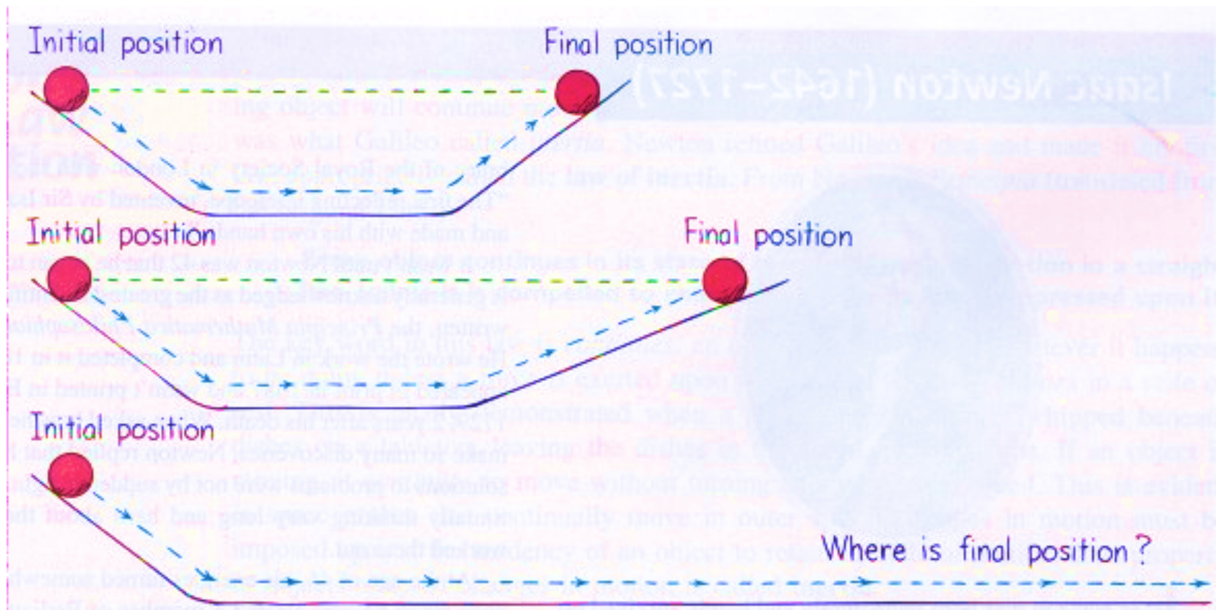
  If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on A.



Newton's First Law

- The first law is a special case of the second law, when there's no net force acting on an object.
  - In that case the object's motion doesn't change.
  - If at rest it remains at rest.
  - If in motion, it remains in uniform motion.
    - Uniform motion is motion at constant speed in a straight line.
    - Uniform motion is a natural state, requiring no extra explanation.





Newton's Second Law

- The second law tells quantitatively how force causes changes in an object's "quantity of motion."
  - Newton defined "quantity of motion," now called **momentum**, as the product of an object's mass and velocity:

$$\boxed{\vec{p} = m\vec{v}}$$

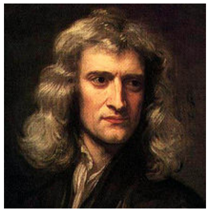
  - Newton's second law equates the rate of change of momentum to the net force on an object:

$$\vec{F} = \frac{\Delta \vec{p}}{\Delta t} = \frac{d\vec{p}}{dt}$$

Yes, that's a derivative

  - When mass is constant, Newton's second law becomes

$$\boxed{\vec{F} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a}}$$



  - The force required to accelerate a 1-kg mass at the rate of 1 m/s^2 is defined to be 1 **Newton** (N).

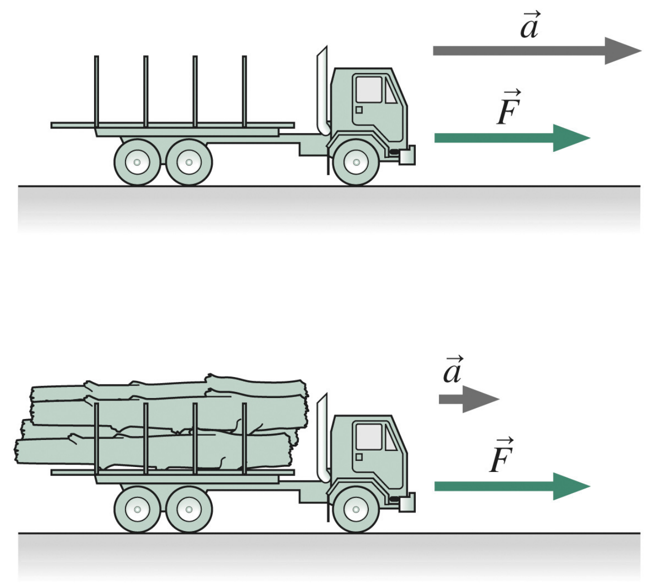
Mass, Inertia and Force

- If we solve the second law for the acceleration we find that

$$\vec{a} = \frac{\vec{F}}{m}$$

showing that a given force is less effective in changing the motion of a more massive object.

  – The mass *m* that appears in Newton's laws is thus a measure of an object's **inertia** and determines the object's response to a given force.



- From Newton's second law for a force of magnitude *F*,

$$\vec{F} = m_{\text{known}}\vec{a}_{\text{known}}, \qquad \vec{F} = m_{\text{unknown}}\vec{a}_{\text{unknown}}$$

we get
$$\frac{m_{\text{unknown}}}{m_{\text{known}}} = \frac{a_{\text{known}}}{a_{\text{unknown}}}$$

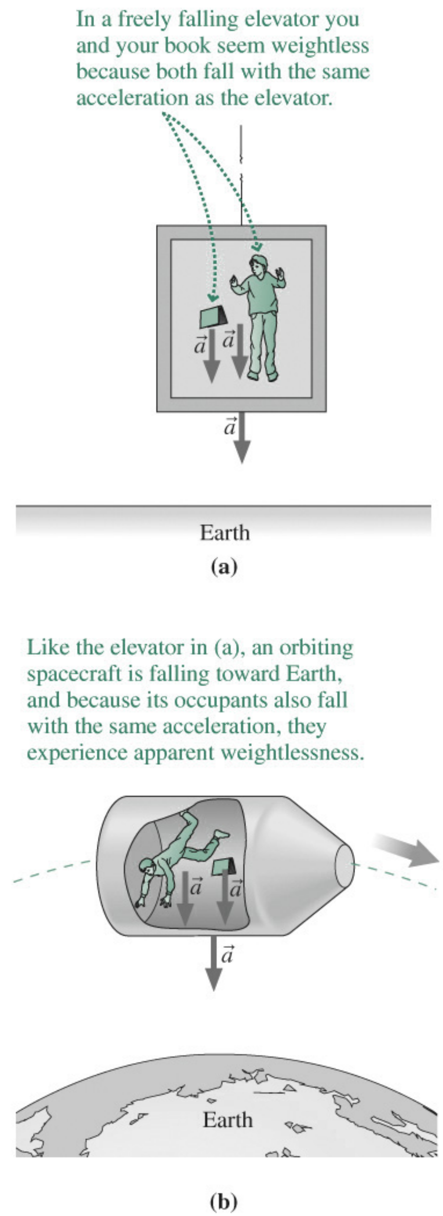
Mass, Weight, and Gravity

- **Weight** is the force of gravity on an object:

$$w = mg$$

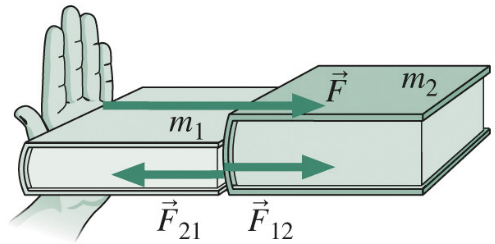
  - **Mass** is a scaler: it doesn't have direction and doesn't depend on the presence or strength of gravity.
  - **Weight** is really a vector: it's a force that depends on gravity (really acceleration, a vector) and varies with location.

- All objects experience the same gravitational acceleration, regardless of mass.
  - Therefore objects in **free fall** with an observer (under the gravity alone) appear **weightless** because they share a common accelerated motion.
  - This effect is noticeable in orbiting spacecraft
    - because the absence of air resistance means gravity is the only force acting.
    - because the apparent weightlessness continues indefinitely, as the spacecraft and its contents "fall" around the Earth.

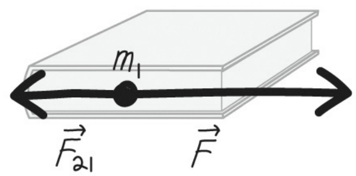


Newton's Third Law

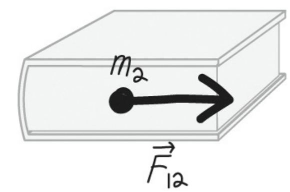
- Forces **always** come in pairs.
  - If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on A.
  - Obsolete language: "For every action there is an equal but opposite reaction."
  - The two forces always act on *different* objects; they can't cancel each other.
- Example:
  - Push on book of mass m_1 with force $\vec{F}$
  - Note third-law pair $\vec{F}_{12}$ and $\vec{F}_{21}$
  - Third law is necessary for a consistent description of motion in Newtonian physics.



(a)

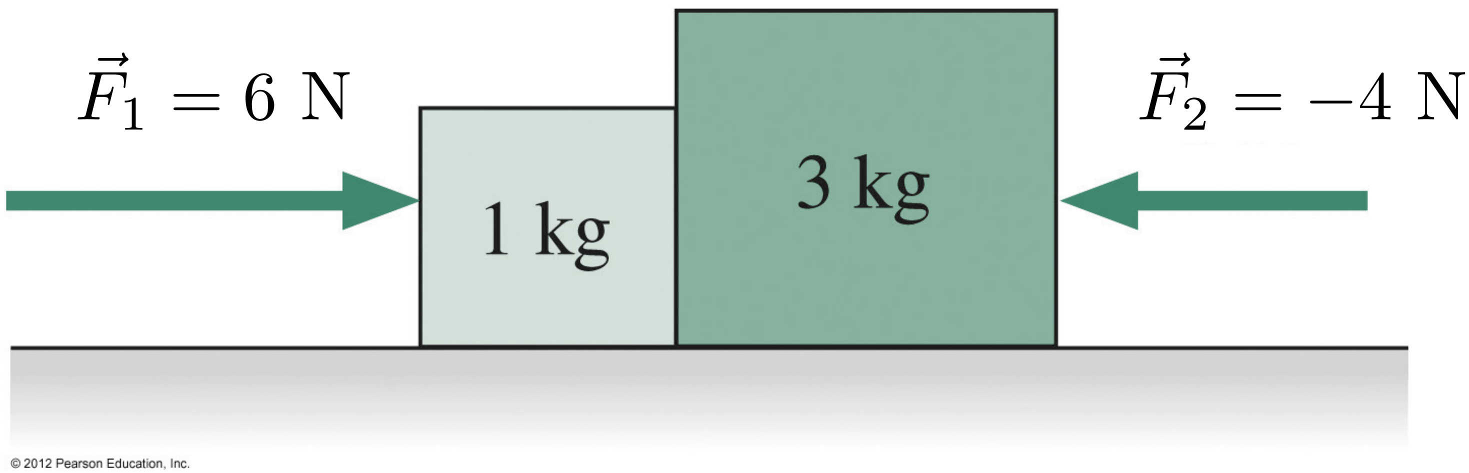


(b)



(c)

Pseudo-Ponderable



This figure shows two blocks with two forces acting on the pair. The net force on the **larger** block is

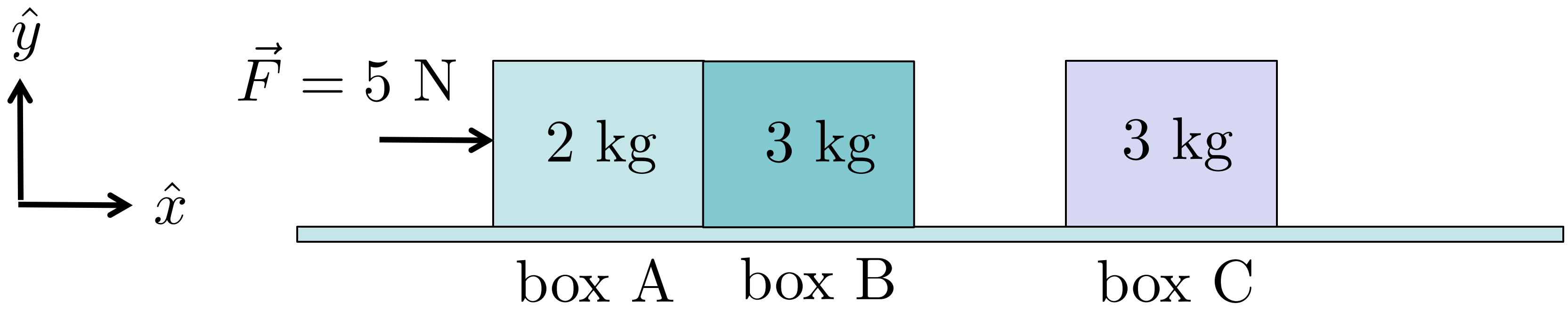
A. Less than 2 N.

B. Equal to 2 N.

C. Greater than 2 N.

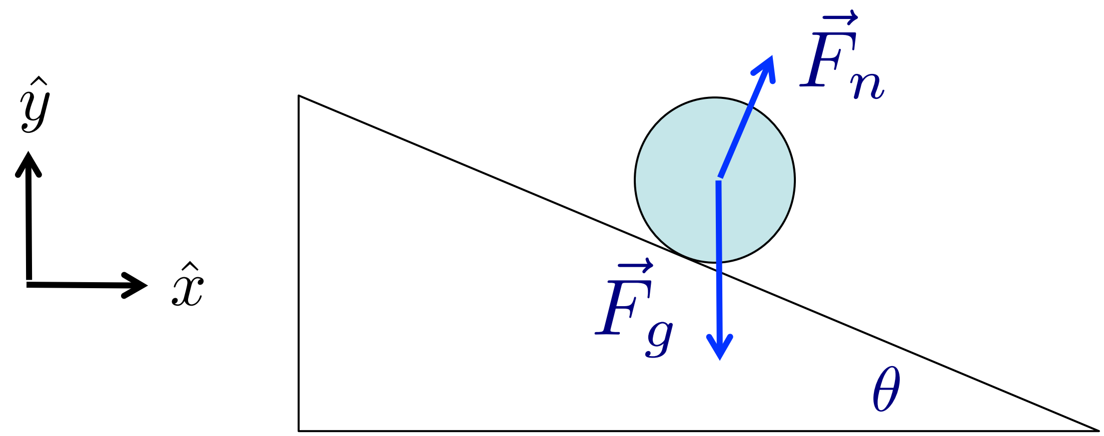
What is the acceleration $\vec{a}$ of each block?

Ponderable (10 minutes)



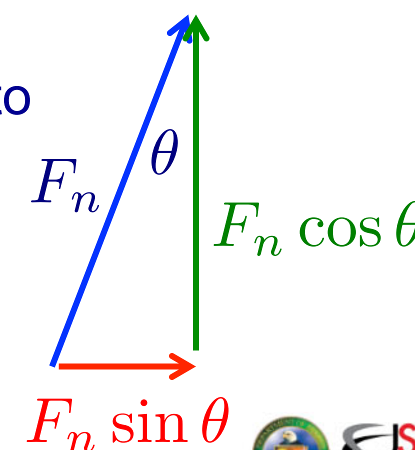
- Draw and label **all** the forces on all three boxes above
  - Assume boxes A and B are touching
  - Assume there is no friction with the table top
  - Assume the force is constant
- What are the initial accelerations of all three boxes?
- What is the acceleration of all three boxes after boxes A and B have hit and move with box C?
- Do boxes A and B slow down (reduce velocity or speed) when they hit box C?

Newton's Second/Third Laws: Tougher Example



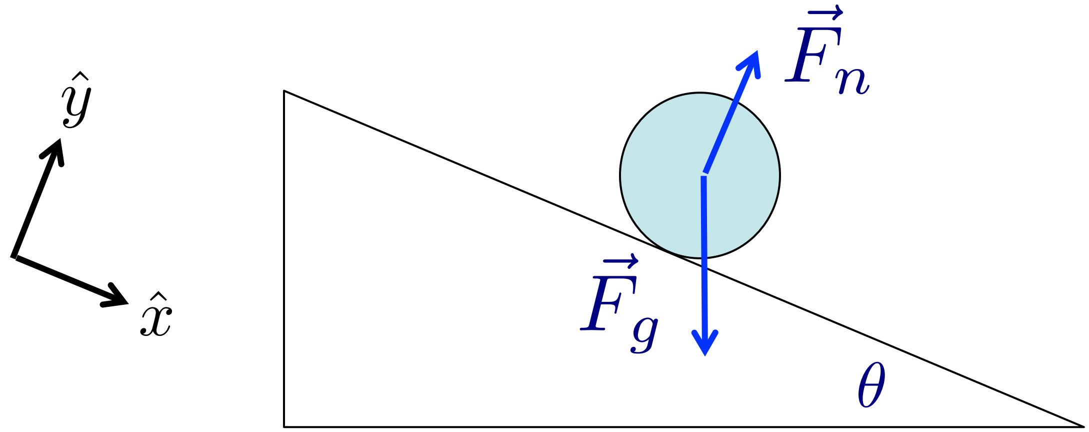
$$m = 5 \text{ kg}$$
$$\theta = 20^\circ$$
$$F_g = mg = 49 \text{ N}$$

- A small ball of m=5 kg is on an inclined plane of 20 degrees
  - What are all the forces acting on the ball? (no friction for now!)
    - Note that forces are vectors: they have direction and magnitude!
    - Two forces: gravity pointing down and push of plane pointing perpendicular to the surface of the plane.
  - **What are the components of the forces**? One way to look at it is with the x,y axes shown above



$$F_{g,x} = 0 \qquad F_{n,x} = F_n \sin\theta$$
$$F_{g,y} = -F_g \qquad F_{n,y} = F_n \cos\theta$$

Newton's Second/Third Laws: Tougher Example



$$m = 5\ \mathrm{kg}$$

$$\theta = 20^\circ$$

$$F_g = mg = 49\ \mathrm{N}$$

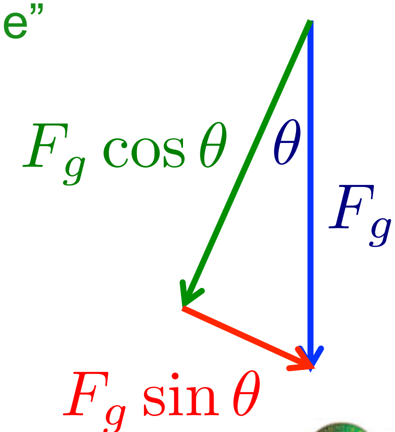
- A small ball of m=5 kg is on an inclined plane of 20 degrees
  - **What are the components of the forces**? Another way to look at it is with axes parallel to and perpendicular to the plane
    - This makes the final acceleration easier to calculate – we know that the net force and acceleration are "down the plane"

$$F_{n,x} = 0$$

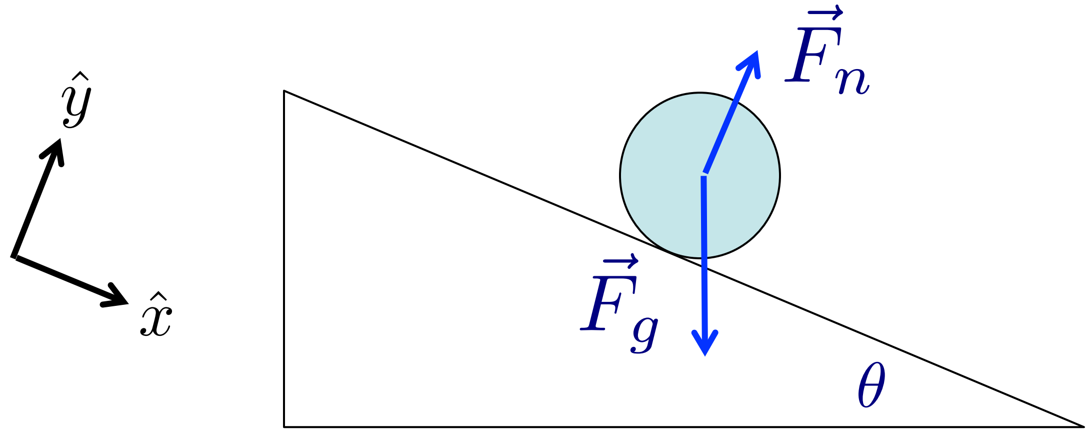
$$F_{n,y} = F_n$$

$$F_{g,x} = F_g \sin\theta$$

$$F_g, y = -F_g \cos\theta$$



Newton's Second/Third Laws: Tougher Example

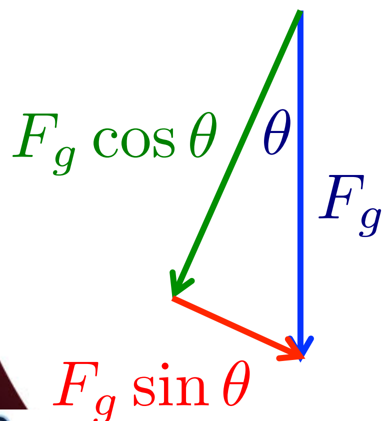


$$m = 5\ \text{kg}$$

$$\theta = 20^\circ$$

$$F_g = mg = 49\ \text{N}$$

- A small ball of m=5 kg is on an inclined plane of 20 degrees
  - **What is the normal force from the plane**, F_n?



$$F_{g,x} = F_g \sin\theta \qquad F_{n,x} = 0$$

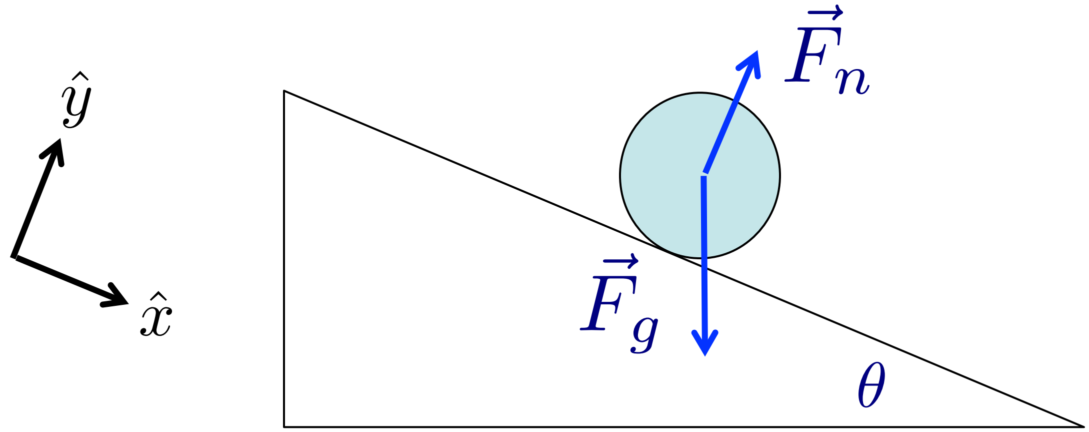
$$F_{g,y} = -F_g \cos\theta \qquad F_{n,y} = F_n$$

$$F_{\text{net,y}} = F_n - F_g \cos\theta = 0$$

No acceleration perpendicular to the plane

$$F_n = F_g \cos\theta = (49\ \text{N}) \cos(20^\circ) = \boxed{46\ \text{N} = F_n}$$

Newton's Second/Third Laws: Tougher Example

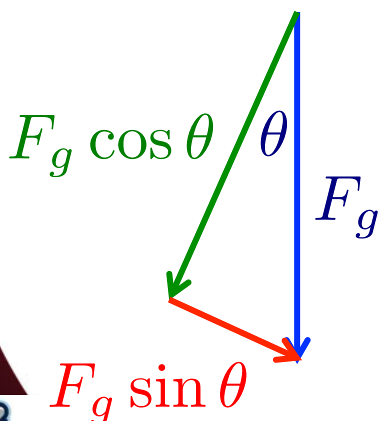


$$m = 5 \text{ kg}$$

$$\theta = 20^\circ$$

$$F_g = mg = 49 \text{ N}$$

- A small ball of m=5 kg is on an inclined plane of 20 degrees
  - **What is the acceleration of the ball down the plane?** a_x



$$F_{g,x} = F_g \sin\theta \qquad F_{n,x} = 0$$

$$F_{g,y} = -F_g \cos\theta \qquad F_{n,y} = F_n$$

$$F_{\text{net,x}} = ma_x = F_{g,x} + F_{n,x} = F_g \sin\theta + 0 = mg\sin(20^\circ)$$

$$a_x = g\sin(20^\circ) = (9.8 \text{ m/s}^2)(0.342) = \boxed{3.35 \text{ m/s}^2 = a_x}$$

Spring Forces

- A stretched or compressed spring produces a force proportional to the stretch or compression from its equilibrium configuration: $F_{sp} = -kx$.

- The spring force is a **restoring force** because its direction is opposite that of the stretch or compression.

- Springs provide convenient devices for measuring force.