Physics 1021

Spring 2011
Chapter 5

ConcepTest 2.1 Newton's First Law II

In which movie(s) is the net force zero

1) A
2) B
3) C
4) A and B
5) A and C
6) B and C
7) All of the movies

A

B

C

PHYS 11: Chap. 2, Pg 2

ConcepTest 2.1 Newton's First Law II

In which movie(s) is the net force zero

1) A
2) B
3) C
4) A and B
5) A and C
6) B and C
7) All three


A


B


C

Only in B is the paramecium moving at a constant velocity (magnitude and direction), and is not accelerating. Thus, there is a net force acting on the other two, A and C.

ConcepTest 2.2 Newton's First Law II

A hockey puck slides on ice at constant velocity. What is the net force acting on the puck?

1) more than its weight
2) equal to its weight
3) less than its weight but more than zero
4) depends on the speed of the puck
5) zero

ConcepTest 2.2 Newton's First Law II

A hockey puck slides on ice at constant velocity. What is the net force acting on the puck?

1) more than its weight
2) equal to its weight
3) less than its weight but more than zero
4) depends on the speed of the puck
5) zero

The puck is moving at a constant velocity, and therefore it is not accelerating. Thus, there must be no net force acting on the puck.

Newton's First Law

New Topic

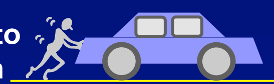
Newton's First Law

Law of Inertia: Objects resist change in motion

Objects do not resist motion, but change in motion

How much do they resist? It depends on their mass.
The more massive an object, the more resistant it will be.

Easy to push 

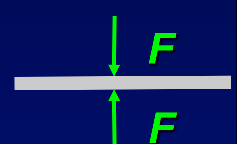
Hard to push 

Mass: How much "stuff" (matter) an object has.

Equilibrium

- Newton's first law implies *Translational* equilibrium:

$$\Sigma F = 0$$



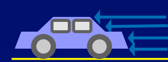
The following statements are equivalent:

- The object is *in equilibrium*
- The *net force on the object is zero*
- The forces acting on the object are *balanced*
- The object is *at rest or moves with constant velocity*
- Every force has another force that balances it. The forces act in interaction pai

A Tour de Force

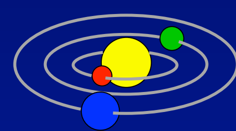
- A force is a push or a pull that acts on an object
  - Contact forces:
    objects in contact exert forces on each other
    - » you push on a box

    - » air pushes on a car (air resistance)



    - » tension in a rope

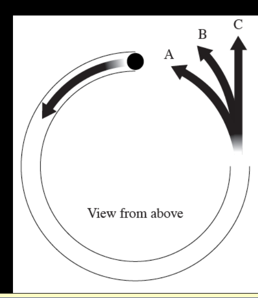
  - Action at a distance:
    - » gravity
    - » electricity
    - » magnetism



***All* forces are vectors!**

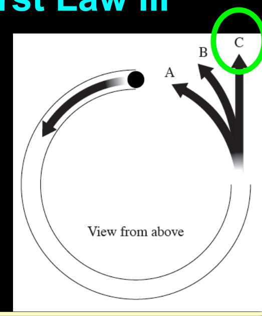
ConcepTest 2.3 Newton's First Law III

A hollow tube forms three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C?



ConcepTest 2.3 Newton's First Law III

A hollow tube forms three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C?



Once the ball exits the tube, the centripetal force is no longer exerted on it to keep accelerating it to the center of the circle. It then flies straight out.

ConcepTest 2.4c Newton's First Law III

You put your book on the bus seat next to you. When the bus stops suddenly, the book slides forward off the seat. Why?

1) **a net force acted on it**
2) **no net force acted on it**
3) **it remained at rest**
4) **it did not move, but only seemed to**
5) **gravity briefly stopped acting on it**

ConcepTest 2.4c Newton's First Law III

You put your book on the bus seat next to you. When the bus stops suddenly, the book slides forward off the seat. Why?

1) a net force acted on it
2) no net force acted on it
3) it remained at rest
4) it did not move, but only seemed to
5) gravity briefly stopped acting on it

The book was initially moving forward (since it was on a moving bus). When the bus stopped, the book **continued moving forward**, which was its **initial state of motion**, and therefore it slid forward off the seat.

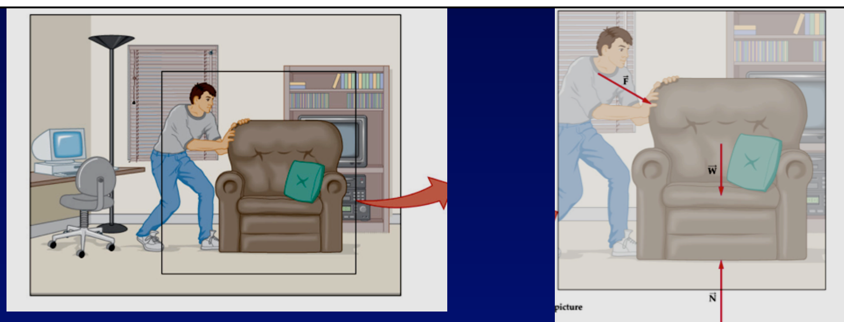
Follow-up: What is the force that usually keeps the book on the seat when stopping?

Whiteboards: Lift the blimp

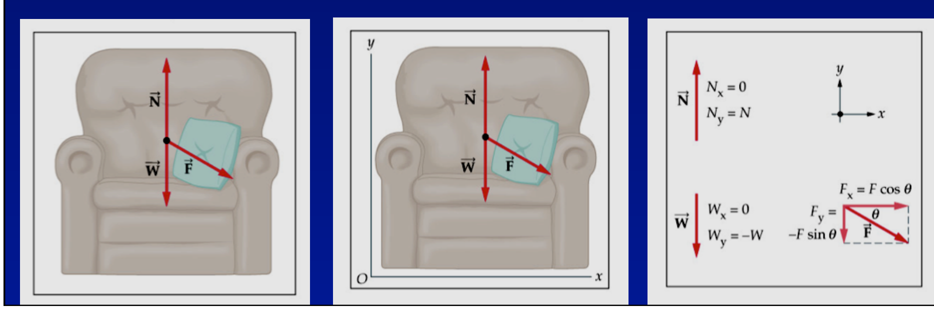
Why is it possible for a single person to pick up the GoodYear blimp (60 m long, 6800 kg), yet they cannot shake it back and forth?

Free-body Diagram

New Topic

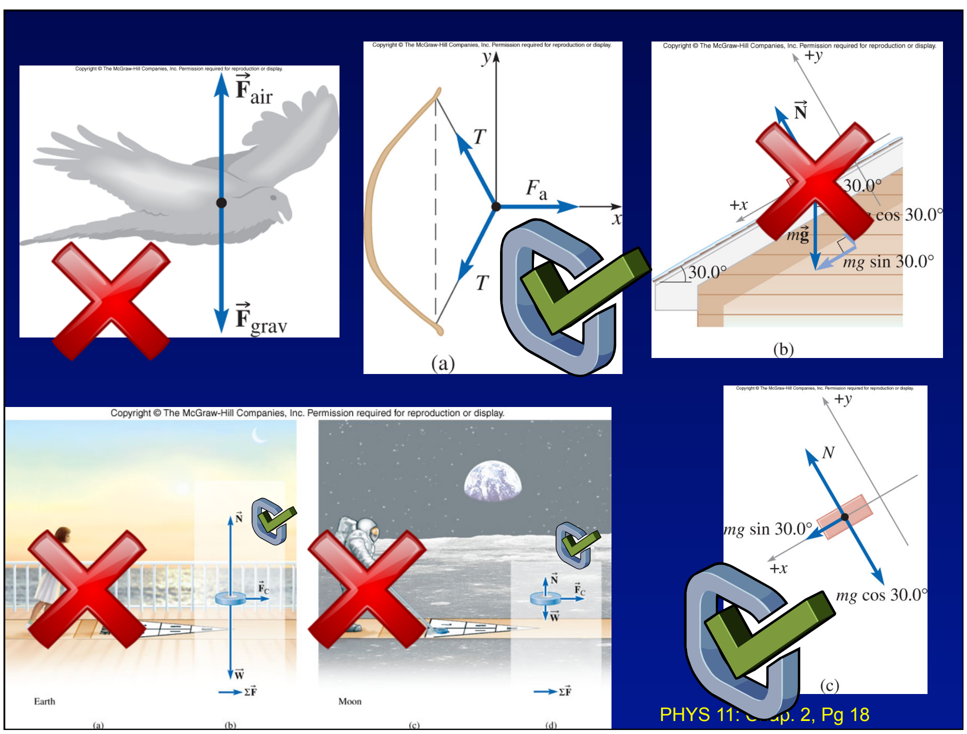


The Free Body Diagram...



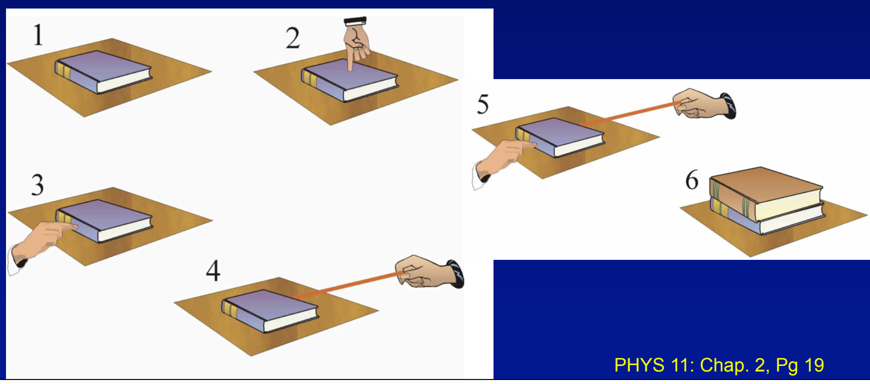
A Free Body Diagram:

- Does not need to be pretty
- Technically a ‘point’ is enough, but a box, circle or schematic representation of the object at hand is enough
- ‘Free Body’ → no other objects, no background, …
- Add the forces acting on the object
- Keep the magnitudes of the vectors roughly in proportion
- Add a coordinate system, choose wisely …



Tangible: Forces on Textbooks

1. For each of the pictures below, draw the free-body diagram on the book. Be careful to include all forces on the book.
2. For 3, 4, and 5 assume that the book has a constant velocity
3. For 3 , push the book to get it moving. Is it more difficult to get the book started or to keep it moving?
4. Redo the free-body diagrams for 3, 4, 5 under the assumption that the book's velocity is changing.
5. For #6, draw the free body diagram for the upper and the lower book and for the books as a single unit.



PHYS 11: Chap. 2, Pg 19

Special Forces:

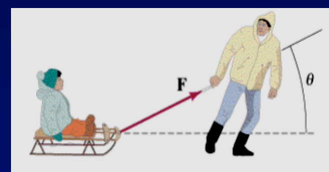
Normal, tension, friction,…

New Topic

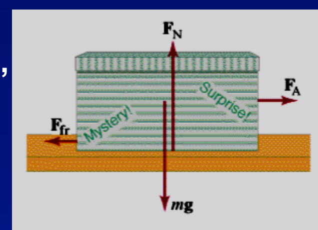
PHYS 11: Chap. 2, Pg 20

Forces can be divided into two classes:

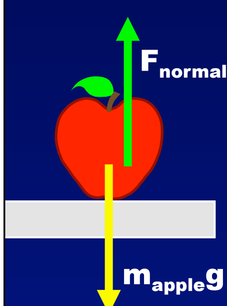
- **Some forces are more Active:** There is a contact force in the form of a pull or push.



- **Others are more Passive:** Where they adjust their size as a “response” to an active force
  - normal force
  - tension
  - friction
  - Centripetal force



Normal force



Why doesn’t the apple fall through the table?

The table exerts a force which stops the apple.

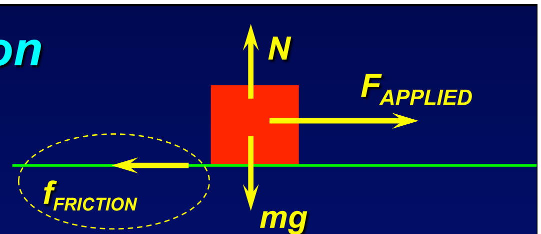
This force is called the NORMAL force

“NORMAL” means *perpendicular*

The NORMAL force is always perpendicular to the surface.

But not necessarily up!

Friction



- What does it do?
  - It opposes motion!
- How do we characterize this?
  - Friction results in a force *parallel* to the surface, in a direction *opposite* to the direction of motion!
  - Frictional force is perpendicular to *N*ormal force
- Kinetic frictional force f_F is proportional to the normal force N .
  - $f_F = \mu_K N$
  - The "heavier" something is,

    the greater the friction will be…. makes sense!

Phys 11: chap 2, Pg 23

Viscous Drag

- What does it do?
  - It opposes motion!
- How do we characterize this?
  - Drag results in a force in a direction *opposite* to the direction of motion!
  - Drag force is proportional to v (small, slow objects) or v^2 (large, fast objects)
- For microscopic objects (paramecium, e.coli).
  - $F_D = \frac{1}{2}\rho c_D A v$ ρ = density, A = area, c_D= drag coefficient, v = velocity
  - The "faster" something goes …

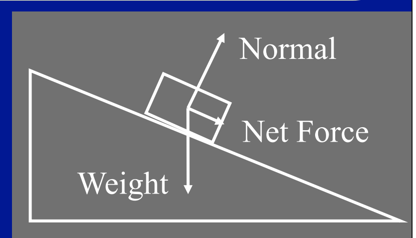
    … the greater the drag will be….

Phys 11: chap 2, Pg 24

ConcepTest 2. 5 Sliding Down I

A box sits on a flat board. You lift one end of the board, making an angle with the floor. As you increase the angle, the box will eventually begin to slide down. Why?

1) component of the gravity force parallel to the plane increased
2) coeff. of static friction decreased
3) normal force exerted by the board decreased
4) both #1 and #3
5) all of #1, #2 and #3



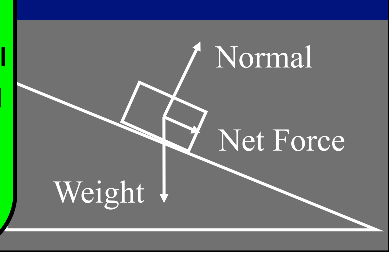
Phys 11: chap 2, Pg 25

ConcepTest 2.5 Sliding Down I

A box sits on a flat board. You lift one end of the board, making an angle with the floor. As you increase the angle, the box will eventually begin to slide down. Why?

1) component of the gravity force parallel to the plane increased
2) coeff. of static friction decreased
3) normal force exerted by the board decreased
4) both #1 and #3
5) all of #1, #2 and #3

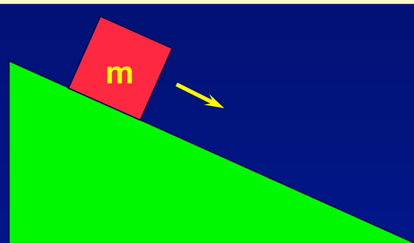
As the angle increases, the **component of weight parallel to the plane increases** and the **component perpendicular to the plane decreases** (and so does the Normal force). Since friction depends on Normal force, we see that the **friction force gets smaller** and the **force pulling the box down the plane gets bigger**.



ConcepTest 2.6 *Sliding Down II*

A mass *m* is placed on an inclined plane ($\mu > 0$) and slides down the plane with constant speed. If a similar block (same μ) of mass *2m* were placed on the same incline, it would:

1) come to a stop
2) slide down with decreasing speed
3) slide down with increasing speed
4) slide down with constant speed
5) slide up with constant speed



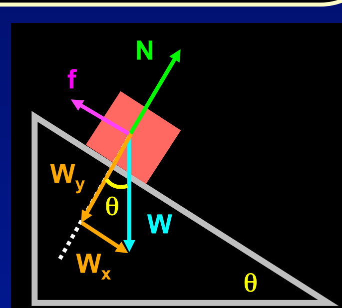
0 of 5

ConcepTest 2.6 Sliding Down II

A mass *m* is placed on an inclined plane ($\mu > 0$) and slides down the plane with constant speed. If a similar block (same μ) of mass *2m* were placed on the same incline, it would:

1) come to a stop
2) slide down with decreasing speed
3) slide down with increasing speed
4) slide down with constant speed
5) slide up with constant speed

The component of gravity acting down the plane is double for *2m*. However, the normal force (and hence the friction force) is also double (the same factor!). This means the two forces still cancel to give a net force of zero.



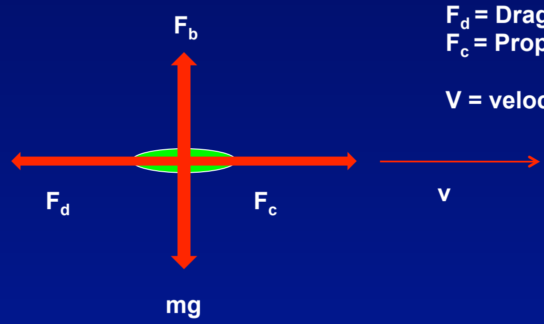
Example:
GOAL

Help
5¢

What are the important forces acting on paramecium swimming horizontally at a constant velocity?

F_b = Buoyant force
F_d = Drag force
F_c = Propulsive force from cilia

V = velocity



Newton's Second Law

Newton's Second Law

$$\sum F = ma$$

Acceleration is proportional to the net force applied

Force is a vector (magnitude and direction)

direction of acceleration = direction of the force

- $\sum F$ is the ***net force*** on the object
  - Net force = vector sum of all the forces = $\sum F$
- mass : inertia, an intrinsic property of an object
  - it is independent of external influences

ConcepTest 2.7 Rubber bands

Two rubber bands stretched the standard distance cause an object to accelerate at 2 m/s². Suppose another object with twice the mass is pulled by four rubber bands stretched the standard length. The acceleration of this second object is

A. 16 m/s^2.
B. 8 m/s^2.
C. 4 m/s^2.
D. 2 m/s^2.
E. 1 m/s^2.

ConcepTest 2.7 Rubber bands

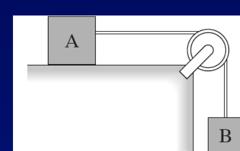
Two rubber bands stretched the standard distance cause an object to accelerate at 2 m/s². Suppose another object with twice the mass is pulled by four rubber bands stretched the standard length. The acceleration of this second object is

A. 16 m/s^2.
B. 8 m/s^2.
C. 4 m/s^2.
D. 2 m/s^2.
E. 1 m/s^2.

The force is doubled, but so is the mass. Thus the two effects cancel and the acceleration is unchanged.

Example: Accelerating block

Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a frictionless table. Draw the FBD for block A



Now the table has friction. Draw the FBD for block A

What is the relationship between the acceleration of block A and the acceleration of block B?

Ponderables: Newton's First and Second Law

A car on a *very slippery icy road is sliding headfirst into a snowbank, where it gently comes to rest* with no one injured. (Question: What does "*very slippery" imply?)*

A compressed spring is pushing a block across a rough horizontal table.

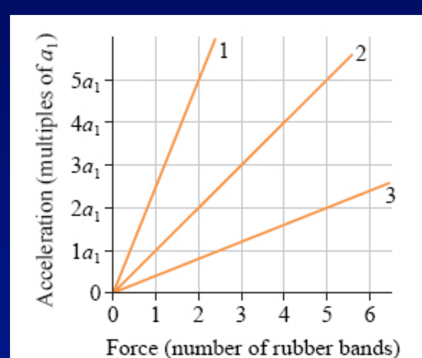
A brick is falling from the roof of a three-story building.

A rocket is launched at a 30° angle. Air resistance is not negligible.

Ponderable: Acceleration vs Force

- The figure shows an acceleration-versus-force graph for three objects pulled by rubber bands. The mass of object 2 is 0.20 kg .

•What is the mass of object 1?
•What is the mass of object 3?



Ponderable: Tossing a stone

You are going to toss a rock *straight up into the air by placing it on the palm of your hand (you're not* gripping it), then pushing your hand up very rapidly. You may want to toss an object into the air this way to help you think about the situation. Draw the free body diagram of the rock:

a. As you hold the rock at rest on your palm, before moving your hand.

b. As your hand is moving up but before the rock leaves your hand

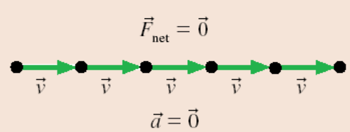
c. One-tenth of a second after the rock leaves your hand.

d. After the rock has reached its highest point and is now falling straight down.

Motion is intrinsic and does not require a force

Newton's First Law

An object at rest will remain at rest, or an object that is moving will continue to move in a straight line with constant velocity, if and only if the net force on the object is zero.



The first law tells us that no "cause" is needed for motion. Uniform motion is the "natural state" of an object.

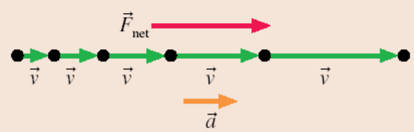
General Principles

Newton's Second Law

An object with mass m will undergo acceleration

$$\vec{a} = \frac{1}{m}\vec{F}_{\text{net}}$$

where $\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$ is the vector sum of all the individual forces acting on the object.



The second law tells us that a net force causes an object to accelerate. This is the connection between force and motion that we are seeking.

Important Concepts

Acceleration is the link to kinematics.

From $\vec{F}_{\text{net}}$, find $\vec{a}$.
From a, find v and x.

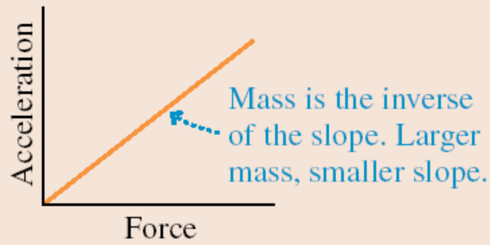
$\vec{a} = \vec{0}$ is the condition for **equilibrium.**

Static equilibrium if $\vec{v} = \vec{0}$.
Dynamic equilibrium if $\vec{v} =$ constant.

Equilibrium occurs if and only if $\vec{F}_{\text{net}} = \vec{0}$.

Important Concepts

Mass is the resistance of an object to acceleration. It is an intrinsic property of an object.



Tactics: Drawing a free-body diagram

TACTICS BOX 5.3 **Drawing a free-body diagram** MP

1. **Identify all forces acting on the object.** This step was described in Tactics Box 5.2.
2. **Draw a coordinate system.** Use the axes defined in your pictorial representation. If those axes are tilted, for motion along an incline, then the axes of the free-body diagram should be similarly tilted.
3. **Represent the object as a dot at the origin of the coordinate axes.** This is the particle model.

Tactics: Drawing a free-body diagram

4. **Draw vectors representing each of the identified forces.** This was described in Tactics Box 5.1. Be sure to label each force vector.
5. **Draw and label the *net force* vector $\vec{F}_{net}$.** Draw this vector beside the diagram, not on the particle. Or, if appropriate, write $\vec{F}_{net} = \vec{0}$. Then check that $\vec{F}_{net}$ points in the same direction as the acceleration vector $\vec{a}$ on your motion diagram.

Exercises 24–29

Even more on FBD

- EOC 5-47: A skier is going down a slope. A *horizontal* headwind is blowing in the skier's face. Friction is small, but not zero. How many force vectors would be shown on a free body diagram?
  - A. 0
  - B. 1
  - C. 2
  - D. 3
  - E. 4
  - F. 5

Even more on FBD

- EOC 5-47: A skier is going down a slope. A *horizontal* headwind is blowing in the skier's face. Friction is small, but not zero. How many force vectors would be shown on a free body diagram?
  - A. 0
  - B. 1
  - C. 2
  - D. 3
  - E. 4
  - F. 5
- Draw the FBD

Phys 11: chap 2, Pg 45