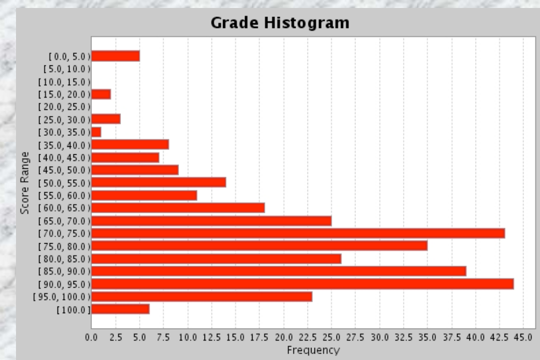
Announcements 4 Mar 09

- Homework
  - Written homework #5 due on Monday
  - Online homework #5 due on Tuesday
- Exam 1
  - Answer keys posted on course web site
  - SPARK grades uploaded
  - Average = 74.3%



Chapter 4
Forces and Newton's Laws of Motion

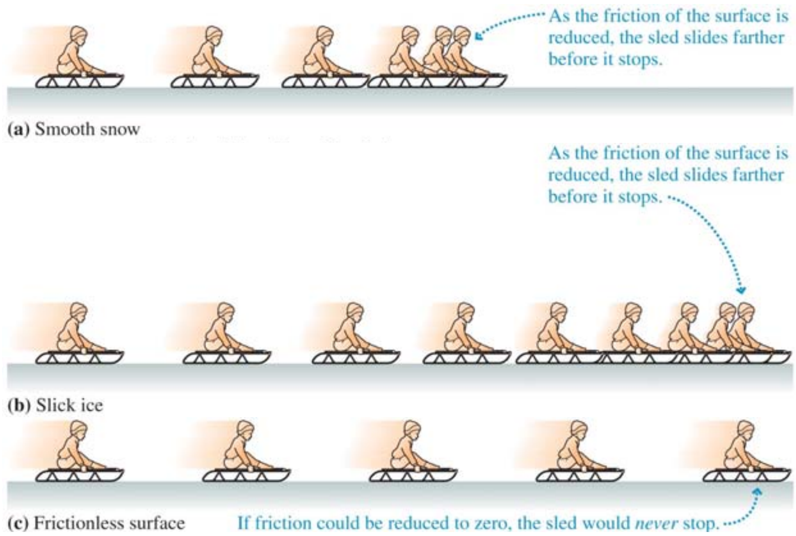
Topics:

- Motion and Newton's first law
- What is a force?
- Identifying forces
- Newton's second law
- Free-body diagrams
- Newton's third law

Sample question:

These ice boats sail across the ice at great speeds. What gets the boats moving in the first place? What keeps them from going even faster?

What Causes Motion?



In the absence of any forces acting on it, an object will continue moving forever. Motion needs no "cause."

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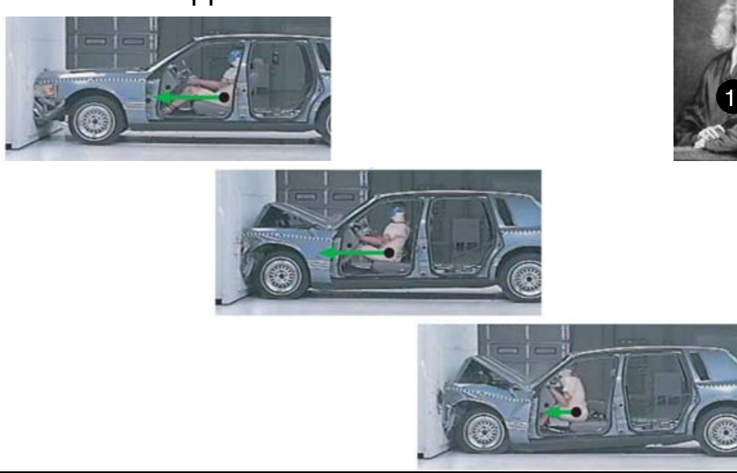
Newton's first law Consider an object with no force acting on it. If it is at rest, it will remain at rest; if it is moving, it will continue to move in a straight line at a constant speed.

Seat belts: An application of Newton's first law.



No cause is needed for motion. Uniform motion is the "natural state" of an object.

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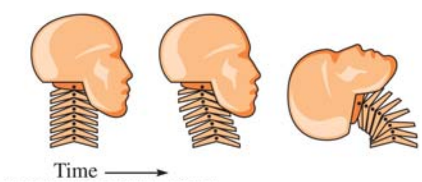
First Law Question

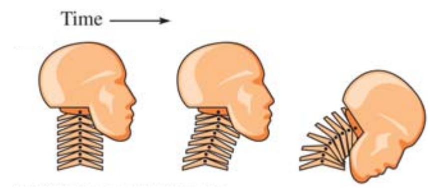
PRS

Whiplash injuries during an automobile accident are caused by the inertia of the head. If someone is wearing a seatbelt, her body will tend to move with the car seat. However, her head is free to move until the neck restrains it, causing damage to the neck.

Which of the two figures corresponds to a rear-end collision?



A.



B.

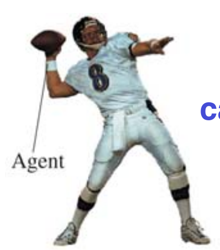
See video clip.

What is a Force?

A force...

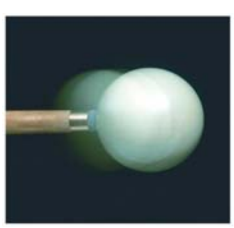
... is a push or pull.

... acts on an object.

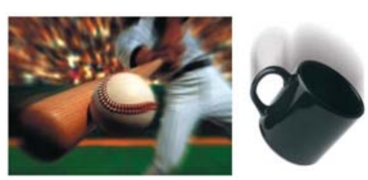


cause

... requires an agent.



... is a vector.



... is a contact force or a long-range force.

Examples of Forces

Demos of different types of forces

Contact forces:
- Pull with hand, string
- Spring
- Book on a table (at rest or moving)

Long range forces:
- Ball drop
- Magnet

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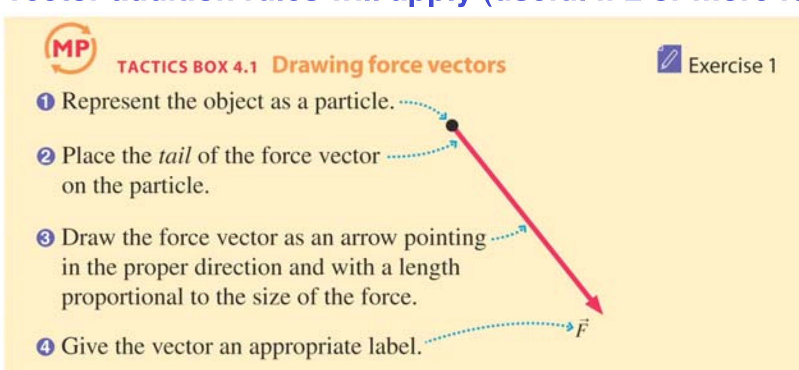
Force Vectors

We will simplify the problem of describing the motion of an object subject to a force:

- Particle model (object represented by a particle)
- Force represented by a vector (with magnitude and direction)

Also, since force is represented by a vector, vector addition rules will apply (useful if 2 or more forces)



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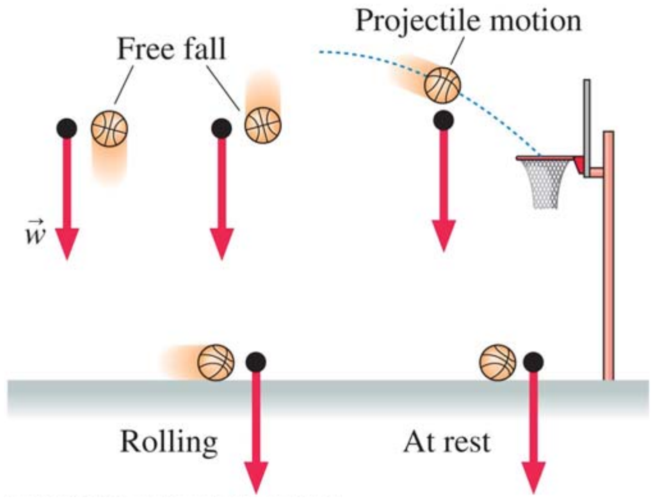
A Short Catalog of Forces: Weight $\vec{w}$



Weight is the gravitational pull of Earth

Beware: **weight is not the same thing as mass**

(force) **(inertia)**

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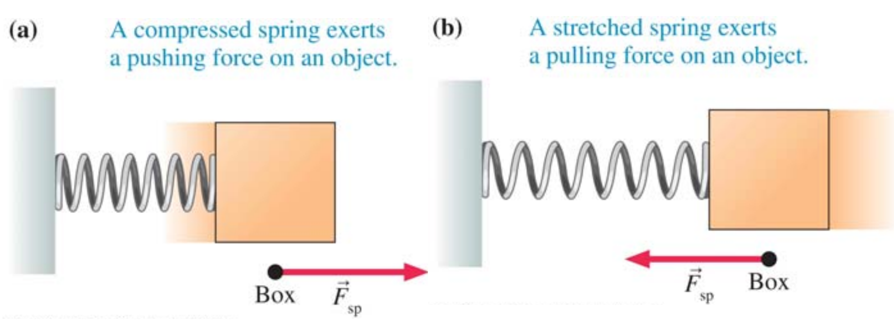
Spring Force $\vec{F}_{sp}$



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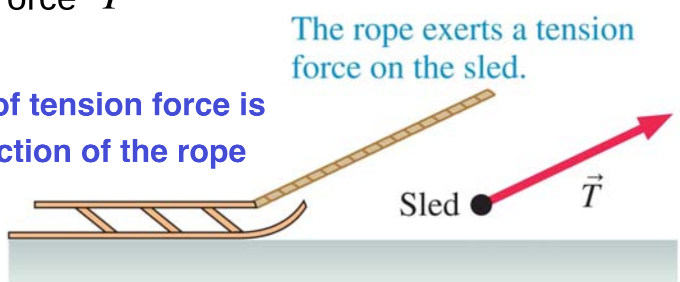
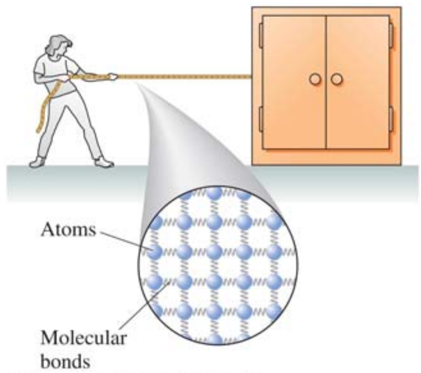
Tension Force $\vec{T}$

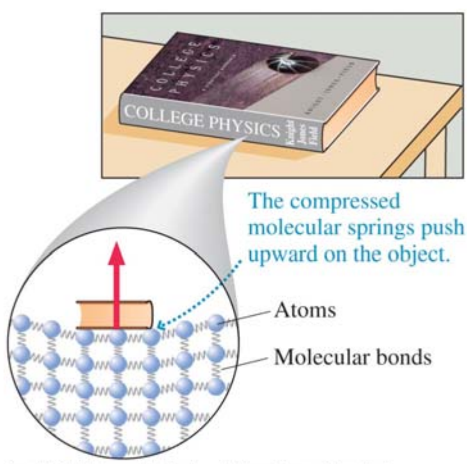
Direction of tension force is along direction of the rope

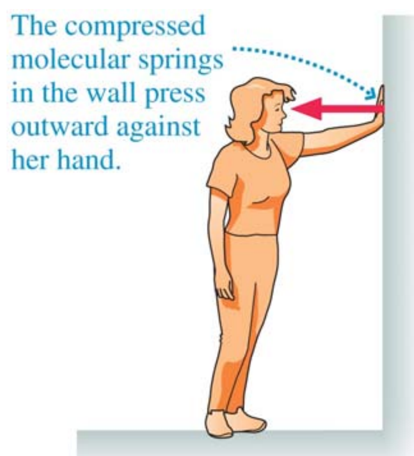




Tension creates stretching of the rope (macroscropic) & stretching of many microscopic strings connected together via molecular bonds

Normal Force $\vec{n}$

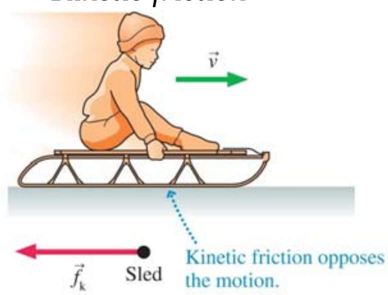




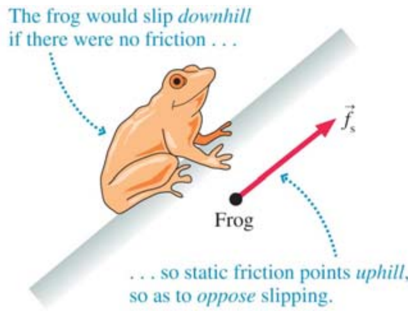
Force exerted by surface on an object in contact with it
Direction is *perpendicular* to the surface, i.e., "normal"

Friction $\vec{f}_k$ and $\vec{f}_s$

Kinetic friction



Static friction



Force exerted by surface on an object in contact with it
Always points in a direction opposite that of the motion
Direction is *parallel* to the surface

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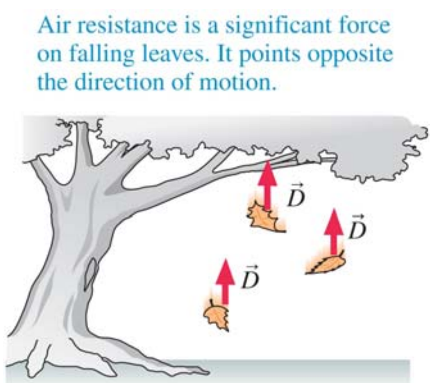
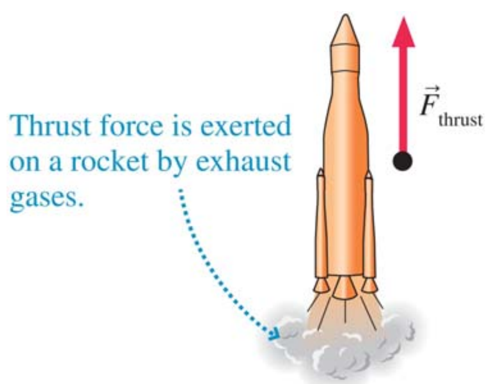
Drag $\vec{D}$ and thrust $\vec{F}_{thrust}$





Drag points in a direction opposite that of the motion

Thrust points in a direction opposite that of the exhaust gases

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How to Solve Force and Motion Problems?

1. Identify all the forces acting on an object
2. Use Newton's laws and kinematics to determine the motion of the object

MP TACTICS BOX 4.2 Identifying forces — Exercises 4–8

❶ **Identify "the system" and "the environment."** The system is the object whose motion you wish to study; the environment is everything else.
❷ **Draw a picture of the situation.** Show the object—the system—and everything in the environment that touches the system. Ropes, springs, and surfaces are all parts of the environment.
❸ **Draw a closed curve around the system.** Only the object is inside the curve; everything else is outside.
❹ **Locate every point on the boundary of this curve where the environment touches the system.** These are the points where the environment exerts *contact forces* on the object.
❺ **Name and label each contact force acting on the object.** There is at least one force at each point of contact; there may be more than one. When necessary, use subscripts to distinguish forces of the same type.
❻ **Name and label each long-range force acting on the object.** For now, the only long-range force is weight.

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Identifying Forces: Example 1

A block is dragged uphill by a rope. Identify all forces acting on the block.

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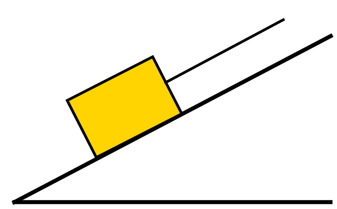

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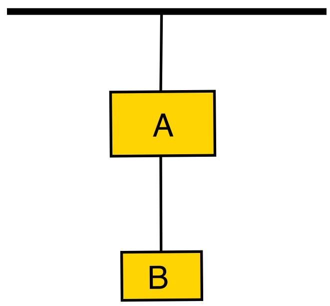
Identifying Forces: Example 2

Block A hangs from the ceiling by a rope. Another block B hangs from A. Identify the forces acting on A.



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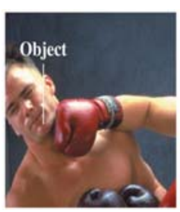
Force and Motion

A force...

CAUSE

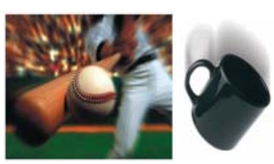
... is a push or pull.



... acts on an object.

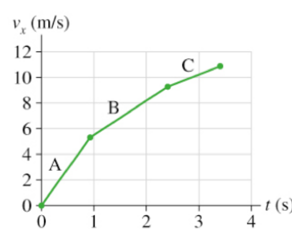
... requires an agent.

... is a vector.



... is a contact force or a long-range force.

EFFECT



acceleration

How are force and motion related?

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Newton's Second Law

Newton's second law An object of mass m subjected to forces $\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$, . . . will undergo an acceleration $\vec{a}$ given by

$$\vec{a} = \frac{\vec{F}_{net}}{m} \qquad (4.5)$$

where the net force $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$ is the vector sum of all forces acting on the object. **The acceleration vector $\vec{a}$ points in the same direction as the net force vector $\vec{F}_{net}$.**

Connection between motion and force

Mass = property of an object that determines how it accelerates in response to an applied force

Units of Force: 1 *Newton* = (1 kg) x (1 m/s^2)

from $\vec{F}_{net} = m\vec{a}$

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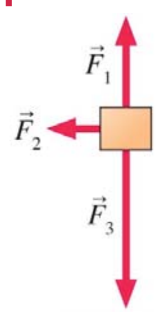
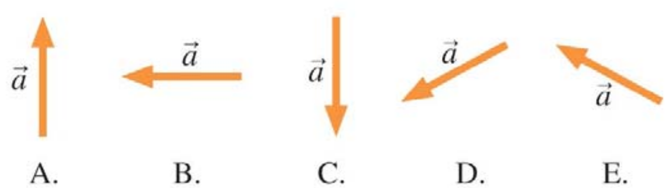
Net Force Question

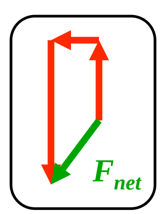
PRS

Three forces act on an object.



In which direction does the object accelerate?





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Free-body Diagrams

MP TACTICS BOX 4.3 **Drawing a free-body diagram** Exercises 17–22

1. **Identify all forces acting on the object.** This step was described in Tactics Box 4.2.
2. **Draw a coordinate system.** Use the axes defined in your pictorial representation (Tactics Box 2.2). 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.
4. **Draw vectors representing each of the identified forces.** This was described in Tactics Box 4.1. 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.

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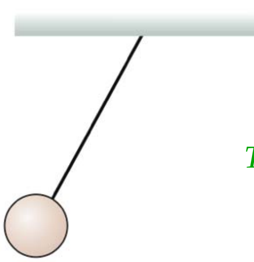
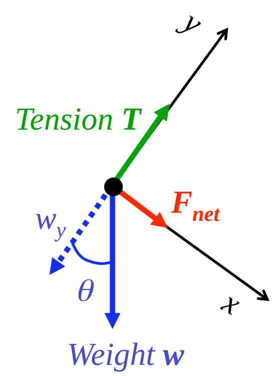
Free-Body Diagram Example

A ball, hanging from the ceiling by a string, is pulled back and released. Draw a free-body diagram just after the ball is released.





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Along string (y axis):

net force = 0

i.e. $T = w_y = w \cos\theta$

$\Rightarrow$ *net force is along x*

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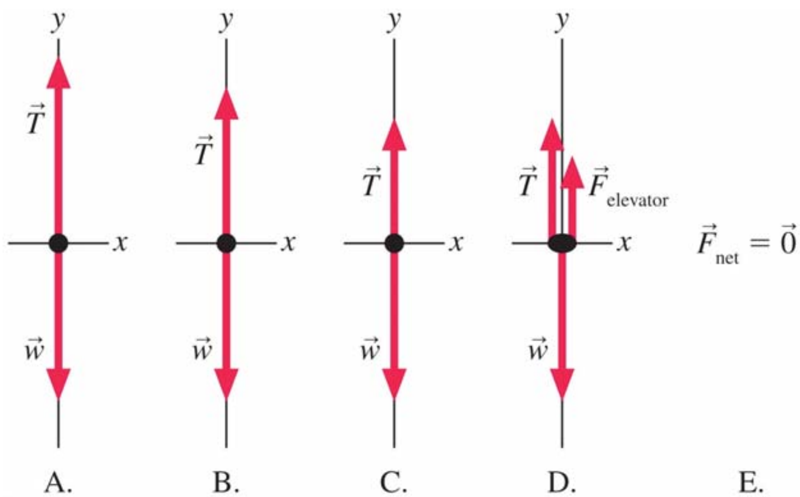
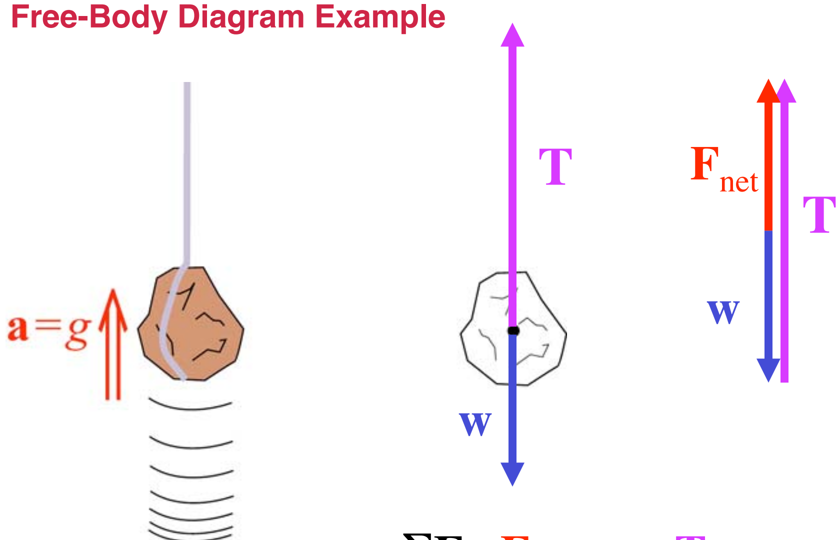
Free-Body Diagram Question

PRS

An elevator suspended by a cable is moving upward and slowing to a stop. Which free-body diagram is correct?



Free-Body Diagram Example



Pulled by string, accelerating upwards at g

$$\Sigma \mathbf{F} = \mathbf{F}_{net} = \mathbf{w} + \mathbf{T} = m\mathbf{a}$$