Announcements

- This week's homework …. 2 parts
- Quiz on Friday, Ch. 4
- Today's class:
  - Newton's second law
  - Friction

Physics 1021

Spring 2012
Chapter 5
and 6

Newton’s Second Law

ConcepTest 2.7 Rubber bands

Two rubber bands stretched the standard distance cause an object to accelerate at 2 m/s^2. 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.

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

Newton's Second Law

$$\sum F = ma$$

Acceleration is **proportional** to the net force applied

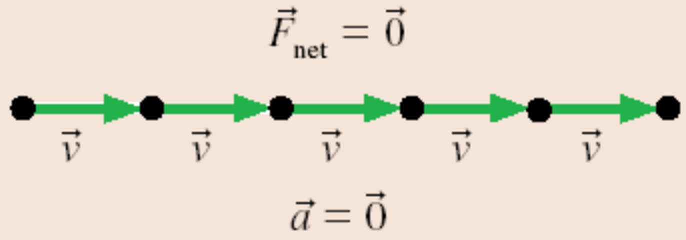
> **Force is a vector (magnitude and direction)**
>
> **direction of acceleration = direction of the force**

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

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.

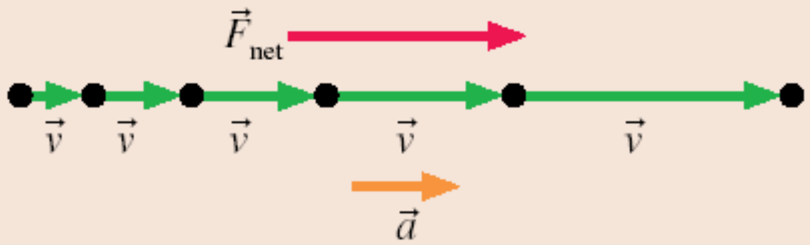
General Principles

Newton's Second Law

An object with mass m will undergo acceleration

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

where $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots$ 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.

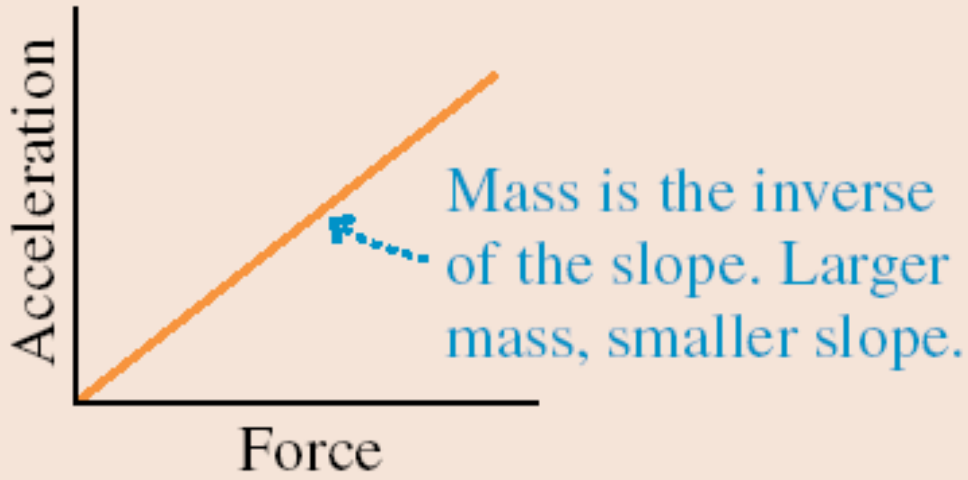
$\vec{a} = \vec{0}$ is the condition for equilibrium.

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.
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

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  - A. 0
  - B. 1
  - C. 2
  - D. 3
  - E. 4
  - F. 5
- Draw the FBD

ConcepTest 6.1 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. Rank the three times below from the largest to the smallest number of forces acting on the stone.

a. the rock at rest on your palm
b. As your hand is moving up but before the rock leaves your hand
c. Instantly after the rock leaves your hand.
d. After the rock has reached its highest point and is now falling straight down.

1. A=D<C<B
2. A<D<C<B
3. A=B<C=D
4. C=D<A=B
5. A<B<C<D

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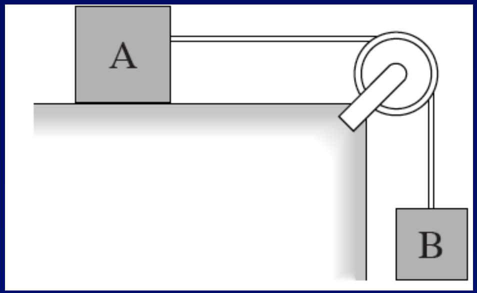
For A and B, there are two forces, gravity and the normal force from the hand. For C and D there is only one for, from gravity.

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?

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.

Ponderables: Newton's First and Second Law
Code words in problems

Find the code word in each statement and tell what it implies about building a model to solve the problem.

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.

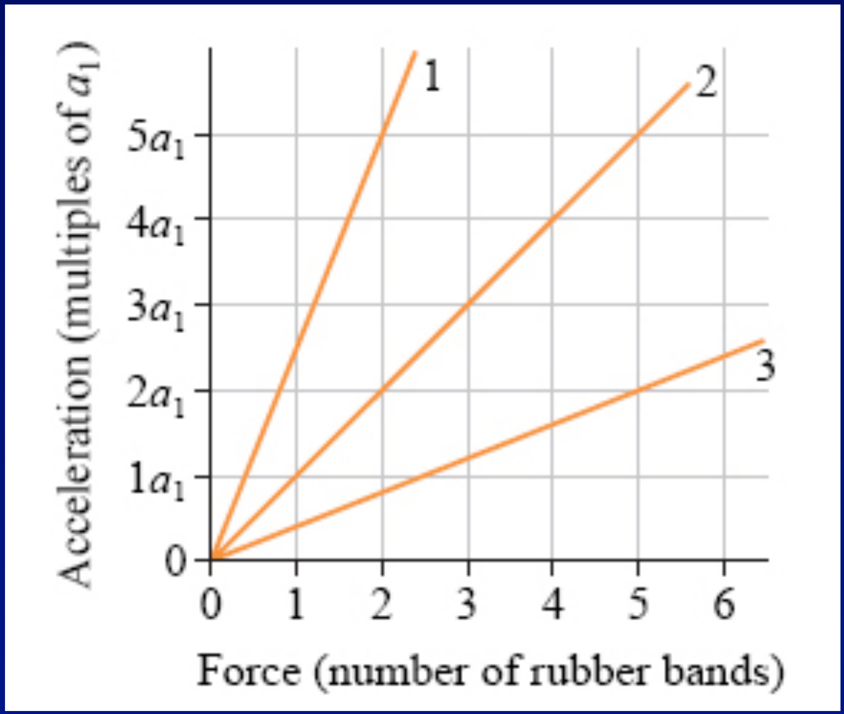
A rocket is launched at a 30° angle. Air resistance is not negligible.

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

Ponderable: Acceleration vs Force

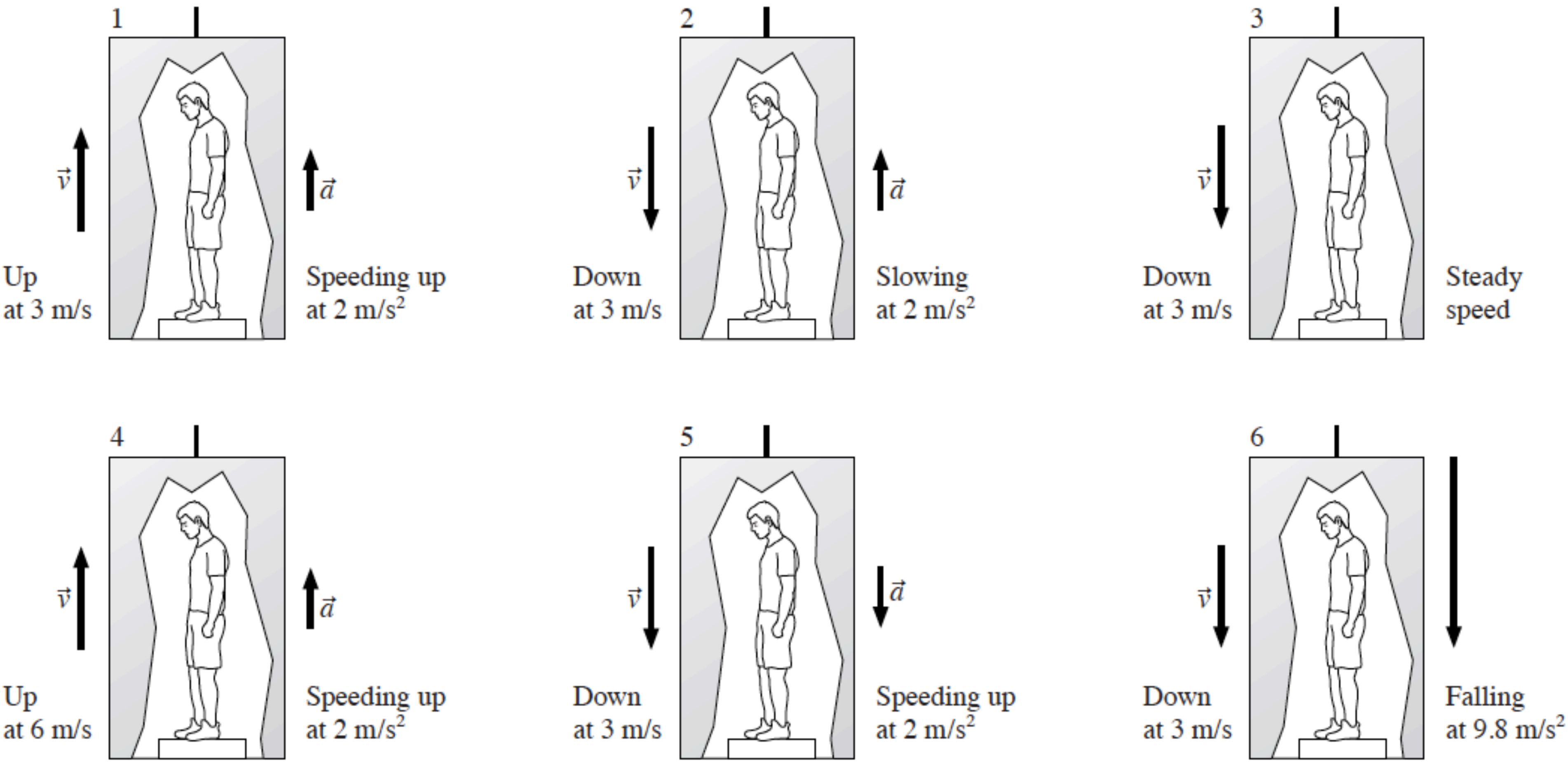
- The figure shows an acceleration-versus-force graph for three objects pulled by rubber bands. The mass of object 2 is 0.20 kg .

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



Ponderable

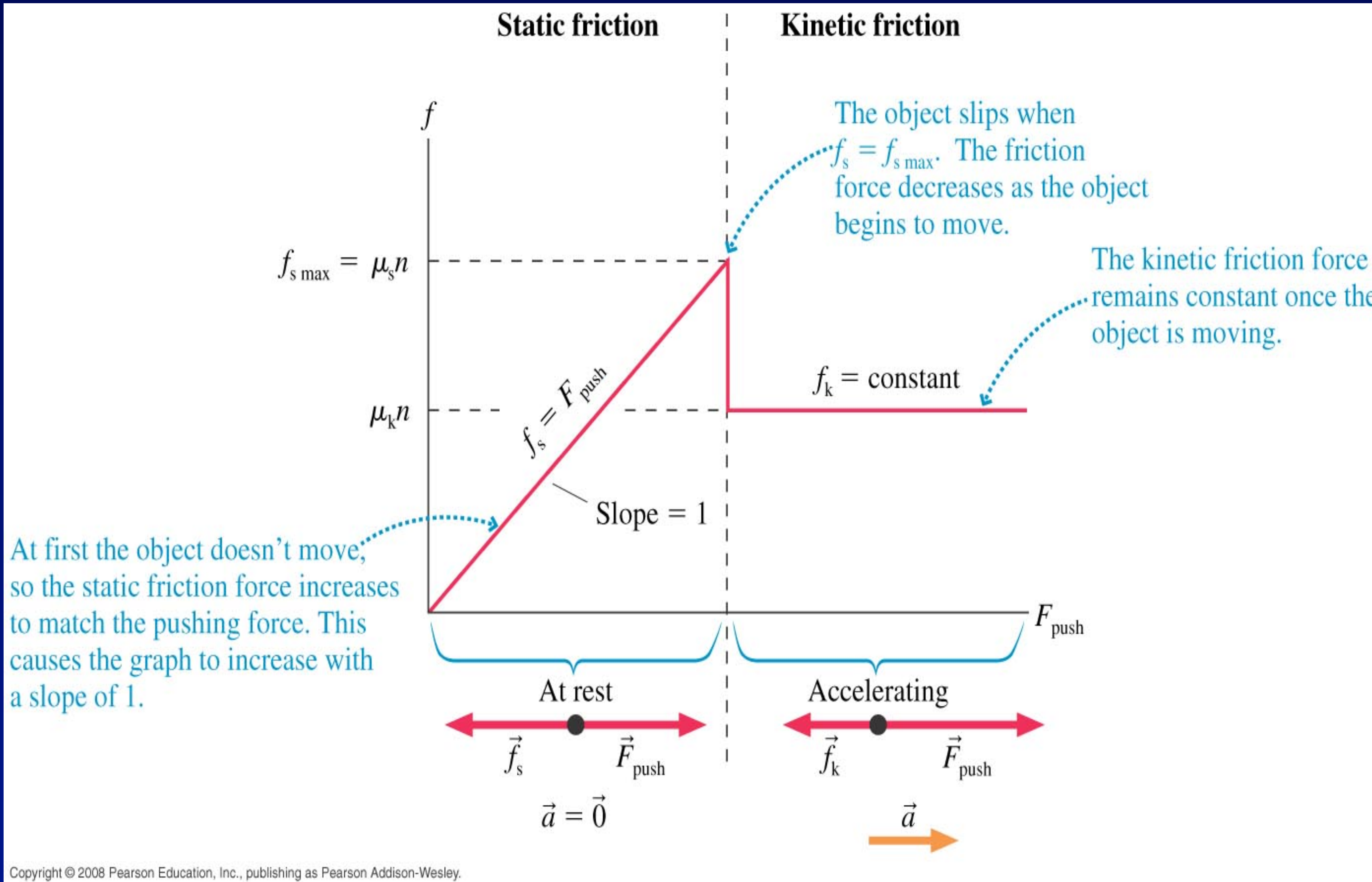
Suppose you stand on a spring scale in six identical elevators. Each elevator moves as shown below. Let the reading of the scale in elevator *n be S_n. Rank in order, from largest to smallest, the six scale readings S_1 to S_6. Some may be equal. Give your answer in the form A>B = C > D.*



Friction

New Topic

Summary of Friction



ConcepTest 6.4 Friction

Rank order, from largest to smallest, the size of the FRICTION forces in these five different situations. The box and the floor are made of the same materials in all situations.

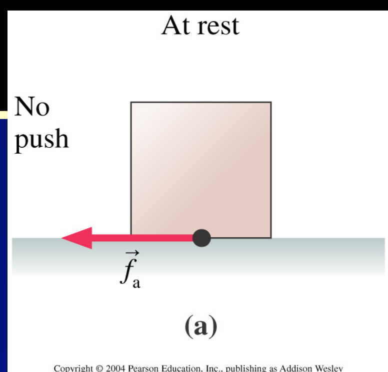
A. $f_c > f_d > f_e > f_b > f_a$.

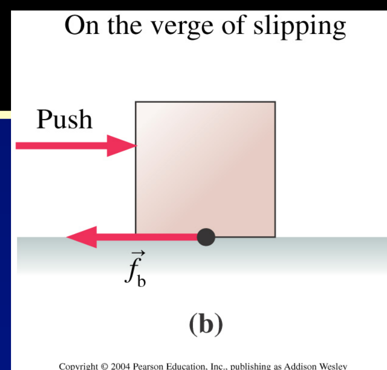
B. $f_b > f_c = f_d = f_e > f_a$

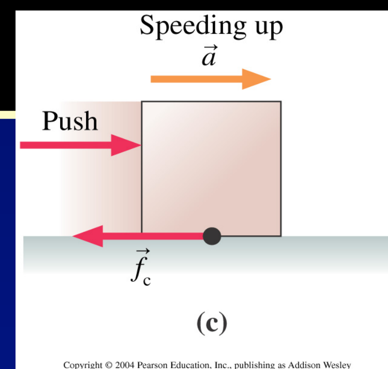
C. $f_b > f_c > f_d > f_e > f_a$.

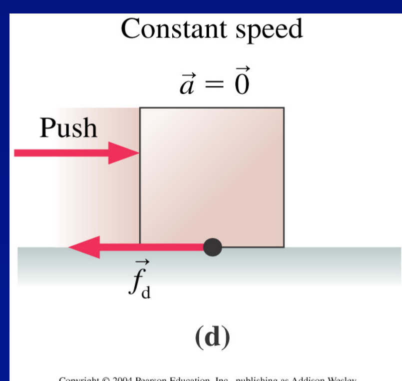
D. $f_a > f_c = f_d = f_e > f_b$.

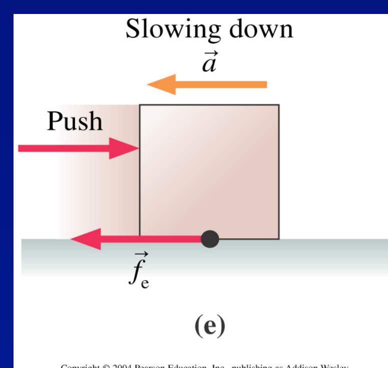
E. $f_a = f_b > f_c = f_d = f_e$.











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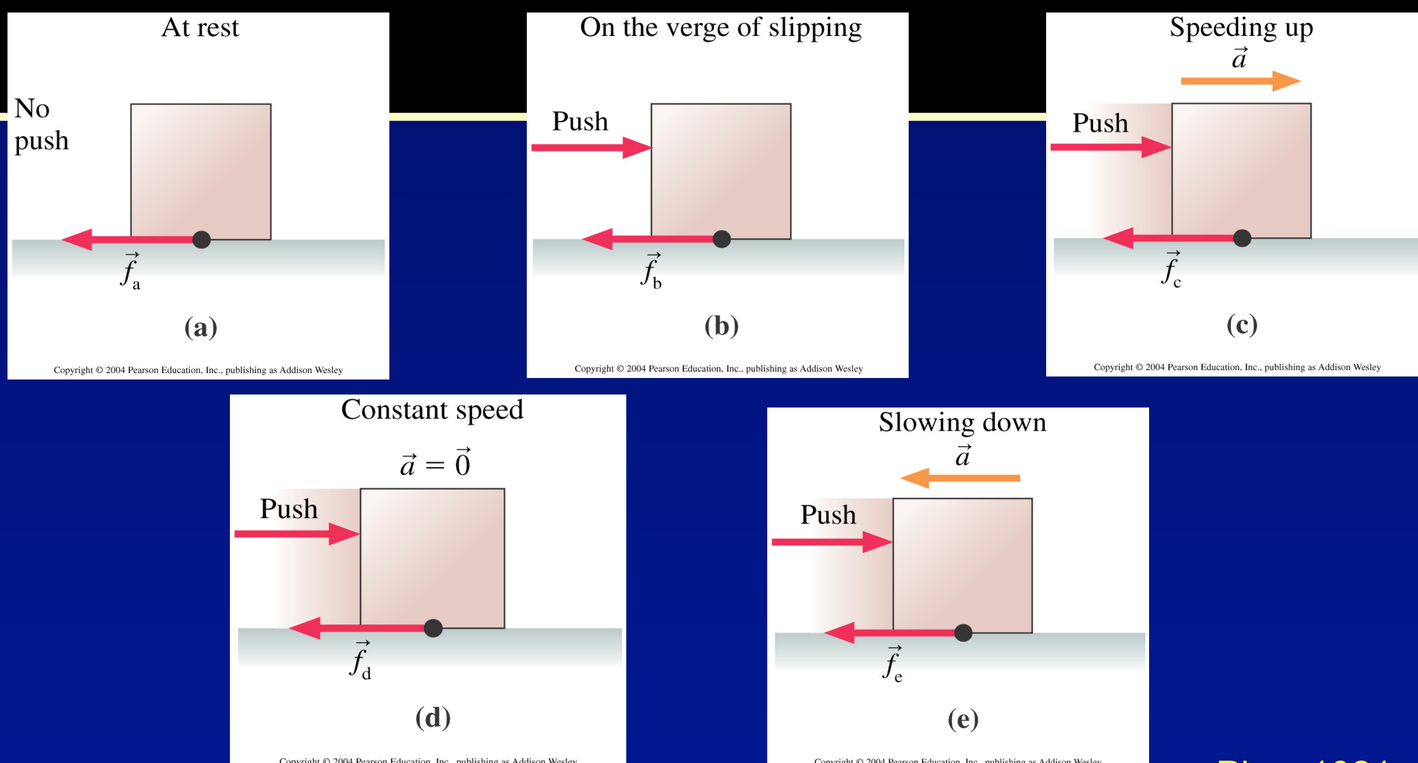

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Rank order, from largest to smallest, the size of the PUSHING forces in these five different situations. The box and the floor are made of the same materials in all situations.

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B. $f_b > f_c = f_d = f_e > f_a$
C. $f_b > f_c > f_d > f_e > f_a$.
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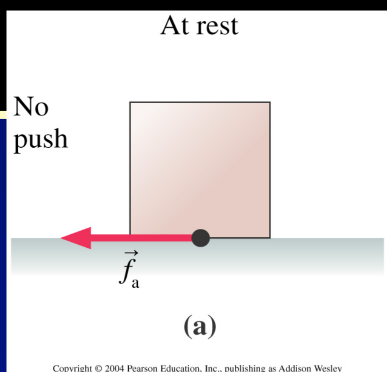

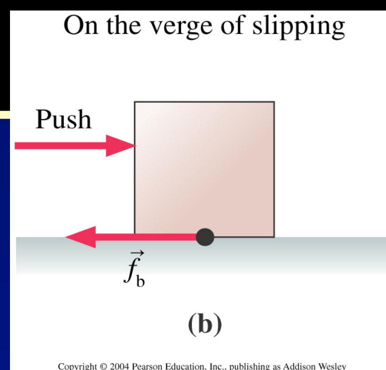

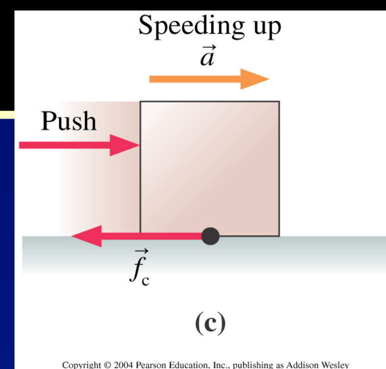

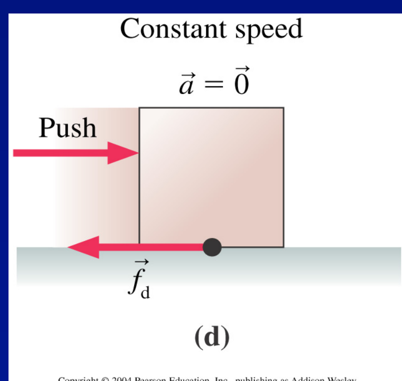

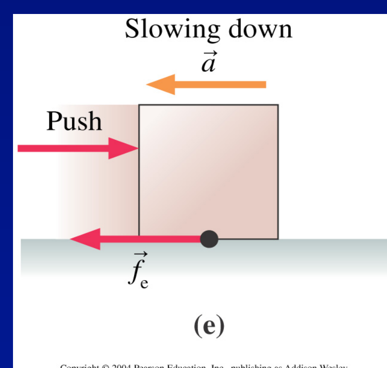

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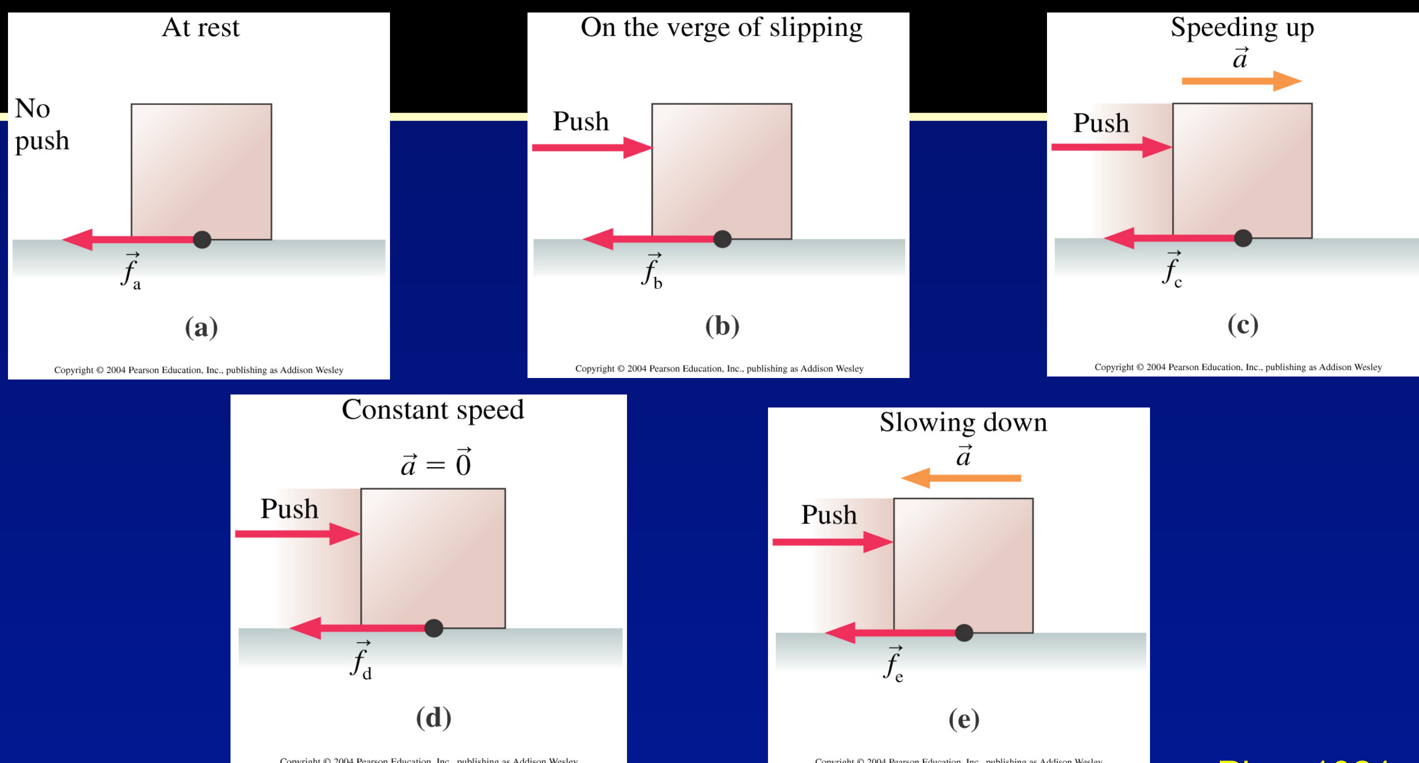

Example

- A 2.0 kg wood box slides down a vertical wood wall at a constant speed while you push upward on it at a 45° angle. For wood on wood, the coefficient of kinetic friction is $\mu_k = 0.20$. What is F_{push}?
- **What magnitude of force should you apply to cause the box to slide down with a 0.1 g acceleration?**