You can draw here

GET READY: Go here and make sure you see the “Are you Ready” Sli.do Q

Canvas -> Course Content -> Lecture (under Week 8 - Chapter 7)

Physics 111 - Lecture 8

October 29, 2020

Do not draw in/on this box!

You can draw here

You can draw here

Reminders/Announcements

- Test 3 (Chapters 6 and 7) starts today from 6PM - Saturday at 6 PM

- Remember: If you want me to record a worked example for content this week, post on the Piazza thread!

- HW is now due Thursdays at 6PM (rather than Wed)

Week 8: Worked Example from Chapter 7

See @346 for details.

Instructions:

- Each student that has a request should create a "Follow-up" discussion to this note
- Make sure to include a screenshot of the full problem (or the text) so I don't have to go digging for it.
- To up-vote the problem, simply click "good note" and I'll pick the top few and record a video (at some point in the week).

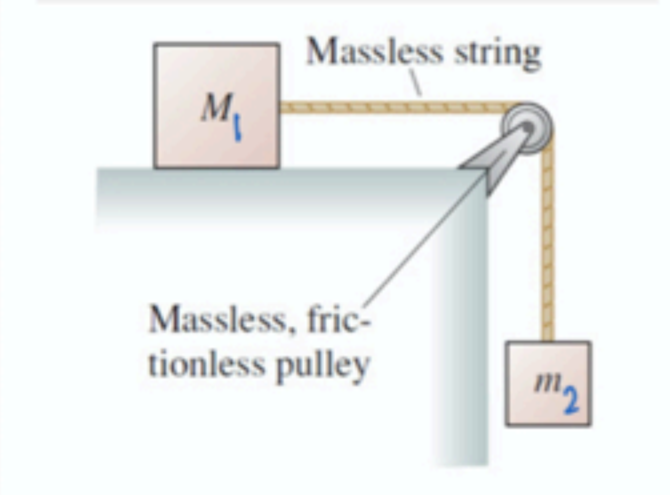
I'll update the post with the worked examples…

The block of mass M in the following figure slides on a frictionless surface.
(Figure 1)

Find tension T in the String.

Figure

1 of 1



FBD

M_1: $\vec{F}_N$, $\vec{T}_1$, $\vec{F}_{1g}$

M_2: $\vec{T}_2$, $\vec{F}_{2g}$

There is only 1 tension!

$T_1 = T_2 = T$

Net Force x and y

X: $\vec{F}_{NET} = \vec{T}$

$m_1 a_x = \vec{T}$

Y: $\vec{F}_{net} = 0$

X: $\vec{F}_{NET} = 0$

Y: $\vec{F}_{NET} = \vec{T} - \vec{F}_{2g}$

$m_2 a_y = \vec{T} - m_2 g$

This minus sign is important! It comes from your convention of which direction is positive or negative!

$-(m_2 a_y) = (\vec{T} - m_2 g)$

But $|a_x| = |a_y| = |a|$! One "system"

$T = m_2 g - m_2 a$

Now, let's substitute T from

By Newton's 2nd Law:

$\vec{F}_{NET} = m_{total} \cdot \vec{a}$

$\vec{a} = \frac{\vec{F}_{NET}}{m_{total}}$ only from m_2!

$$\boxed{\vec{a} = \frac{m_2 g}{m_1 + m_2}}$$

Reminders/Announcements

	Homework (due Thurs 6 pm)	Test/Bonus Test (Thurs 6pm - Sat 6pm)	Learning Log (Sat 6pm)
Week 1	-	-	-
Week 2	HW01 - Intro to Mastering Physics	Test 0 **(not for marks)**	Learning Log 1
Week 3	HW02 - Chapter 2 HW03 - Chapter 3	Test 1 (on Chapters 2 & 3)	Learning Log 2
Week 4	HW04 - Chapter 4	Bonus Test 1	Learning Log 3
Week 5	HW05 - Chapter 5	Test 2 (on Chapters 4 and 5)	Learning Log 4
Week 6	N/A	N/A	N/A
Week 7	HW07 - Chapter 6	Bonus Test 2	Learning Log 5
Week 8	HW08 - Chapter 7	Test 3	Learning Log 6
Week 9	HW09 - Chapter 8	Bonus Test 3	Learning Log 7
Week 10	HW10 - Chapter 9 (deadline extended)	Test 4 (window moved to Sun Nov 15 - Tues Nov 17 due to Fall mini-break)	No Learning Log

Summary of comments from Homework 8 (Chapter 7)

Students Completed

65 / 322

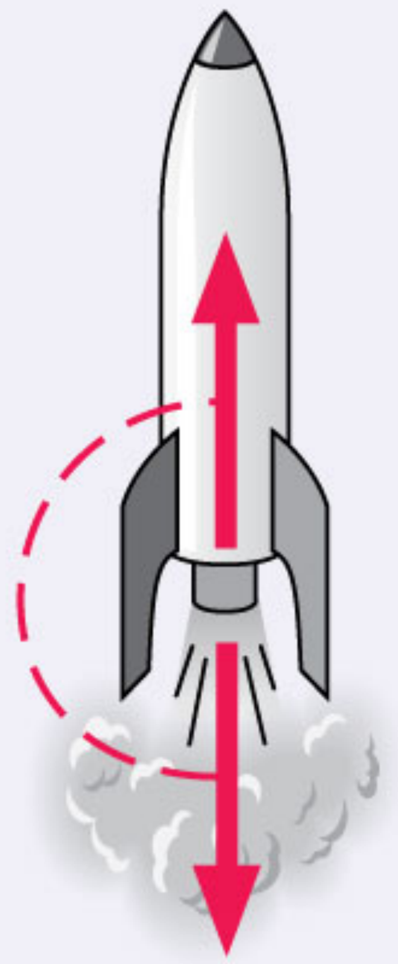
Let’s chalk this up Labs?

Chapter 7
Important Concepts

What is Newton's third law?

Newton's third law governs interactions:

- Every force is a member of an action/reaction pair.
- The two members of a pair act on different objects.
- The two members of a pair are equal in magnitude but opposite in direction.



Why is Newton's third law important?

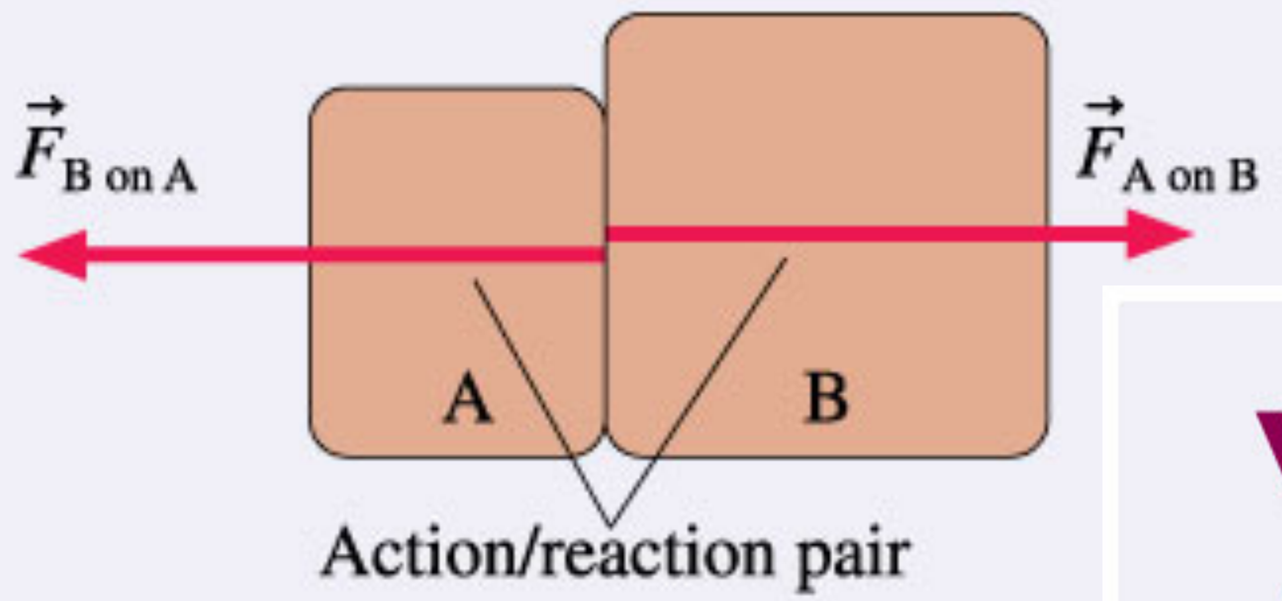
We started our study of dynamics with only the first two of Newton's laws in order to practice identifying and using forces. But objects in the real world don't exist in isolation—they *interact* with each other. Newton's third law gives us a much more complete view of mechanics. The third law is also an essential tool in the practical application of physics to problems in engineering and technology.

Newton's Third Law

Every force occurs as one member of an **action/reaction pair** of forces. The two members of an action/reaction pair:

- Act on two *different* objects.
- Are equal in magnitude but opposite in direction:

$$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$$



What is an interaction?

All forces are interactions in which objects exert forces on each other. If A pushes on B, then B pushes back on A. These two forces form an action/reaction pair of forces. One can't exist without the other.

« LOOKING BACK Section 5.5 Forces, interactions, and Newton's second law

Objects, systems, and the environment

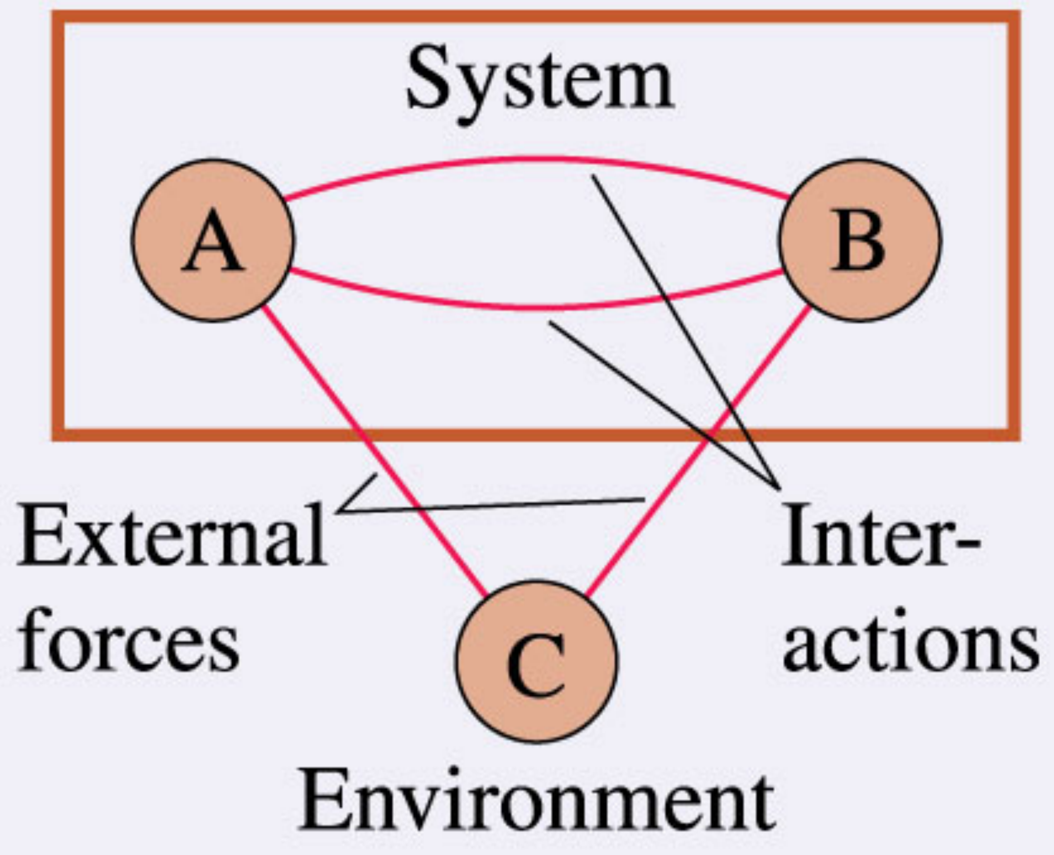
Objects whose motion is of interest are the system.

Objects whose motion is not of interest form the environment.

The objects of interest interact with the environment, but those interactions can be considered external forces.

What is an interaction diagram?

We will often analyze a problem by defining a system—the objects of interest—and the larger environment that acts on the system. An interaction diagram is a key visual tool for identifying action/reaction forces of interaction *inside* the system and external forces from agents in the environment.



Interacting Objects

- When a bat hits a ball, the ball exerts a force on the bat.
- When you pull someone with a rope in a tug-of-war, that person pulls back on you.

The bat and the ball are interacting with each other.

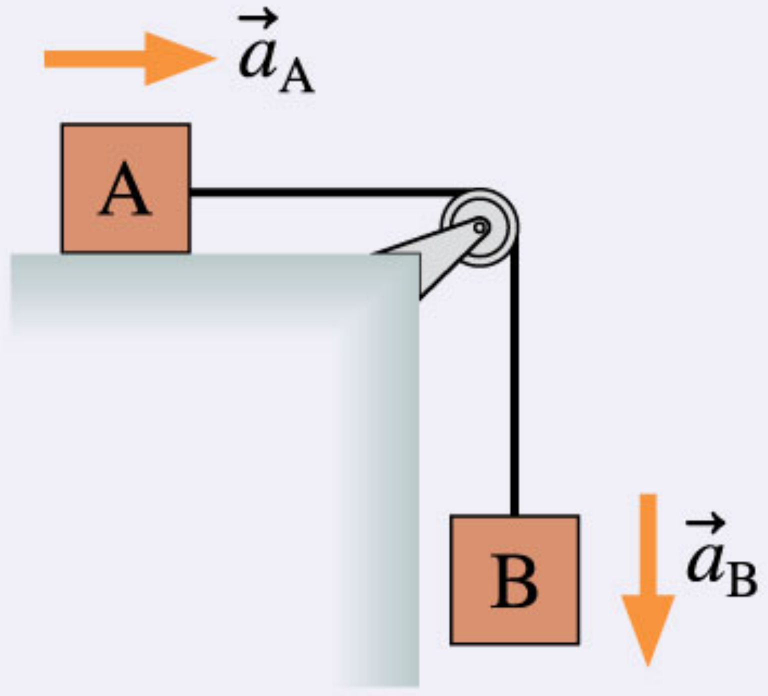
- When your chair pushes up on you (the normal force), you push down on the chair.
- All forces come in pairs, called **action/reaction pairs**.
- These forces occur simultaneously, and we cannot say which is the "action" and which is the "reaction."

How do we model ropes and pulleys?

A common way that two objects interact is to be connected via a rope or cable or string. Pulleys change the direction of the tension forces. We will often model

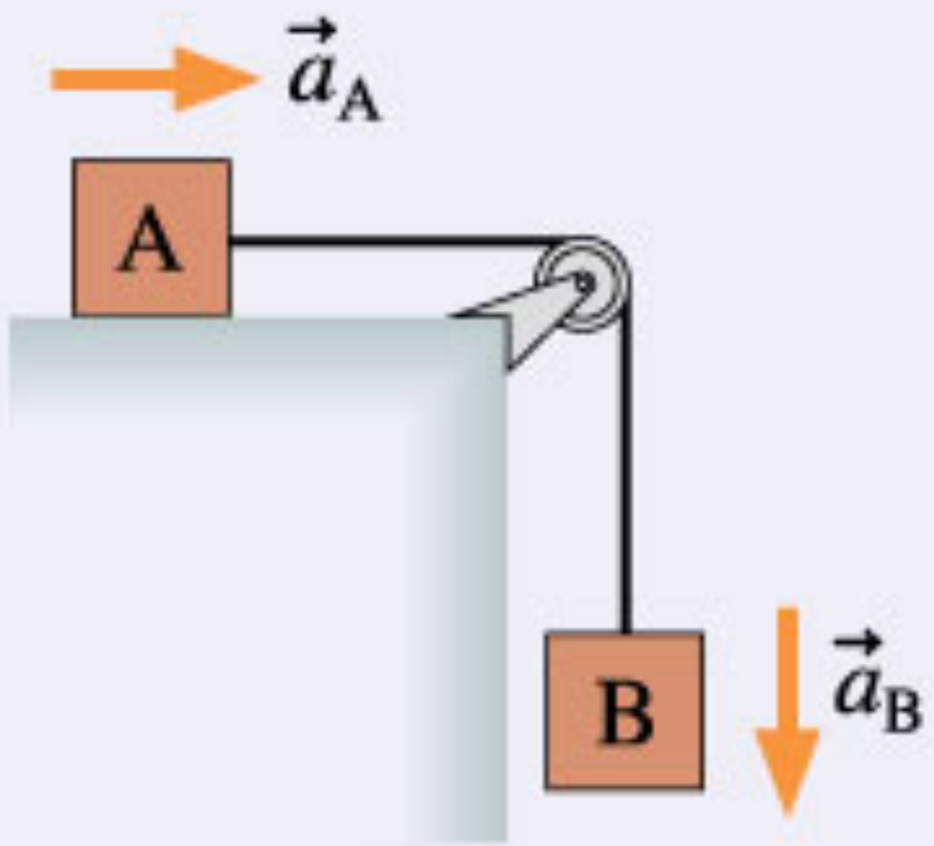
- Ropes and strings as massless;
- Pulleys as massless and frictionless.

The objects' accelerations are constrained to have the same magnitude.



Acceleration constraints

Objects that are constrained to move together must have accelerations of equal magnitude: $a_A = a_B$. This must be expressed in terms of components, such as $a_{Ax} = -a_{By}$.

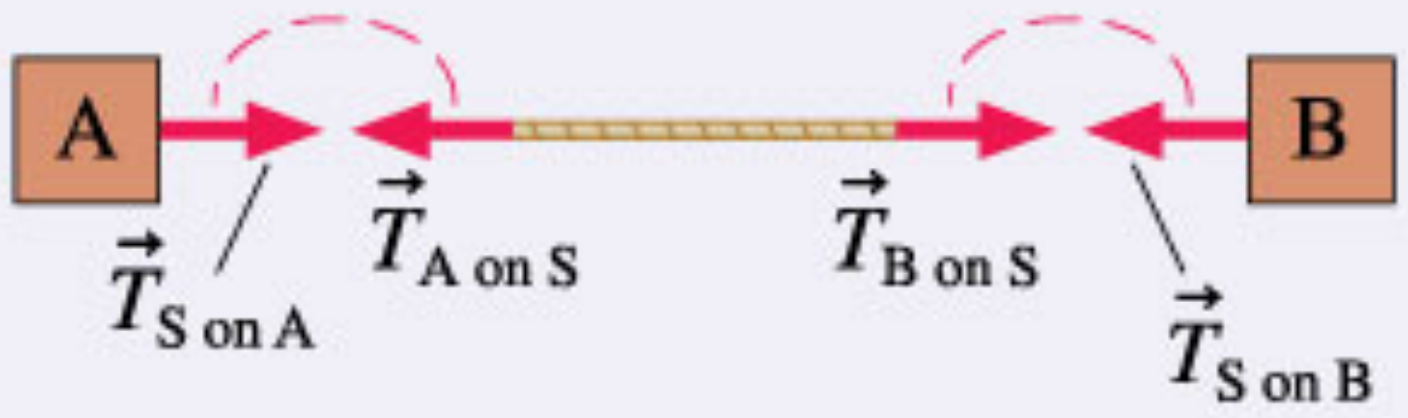


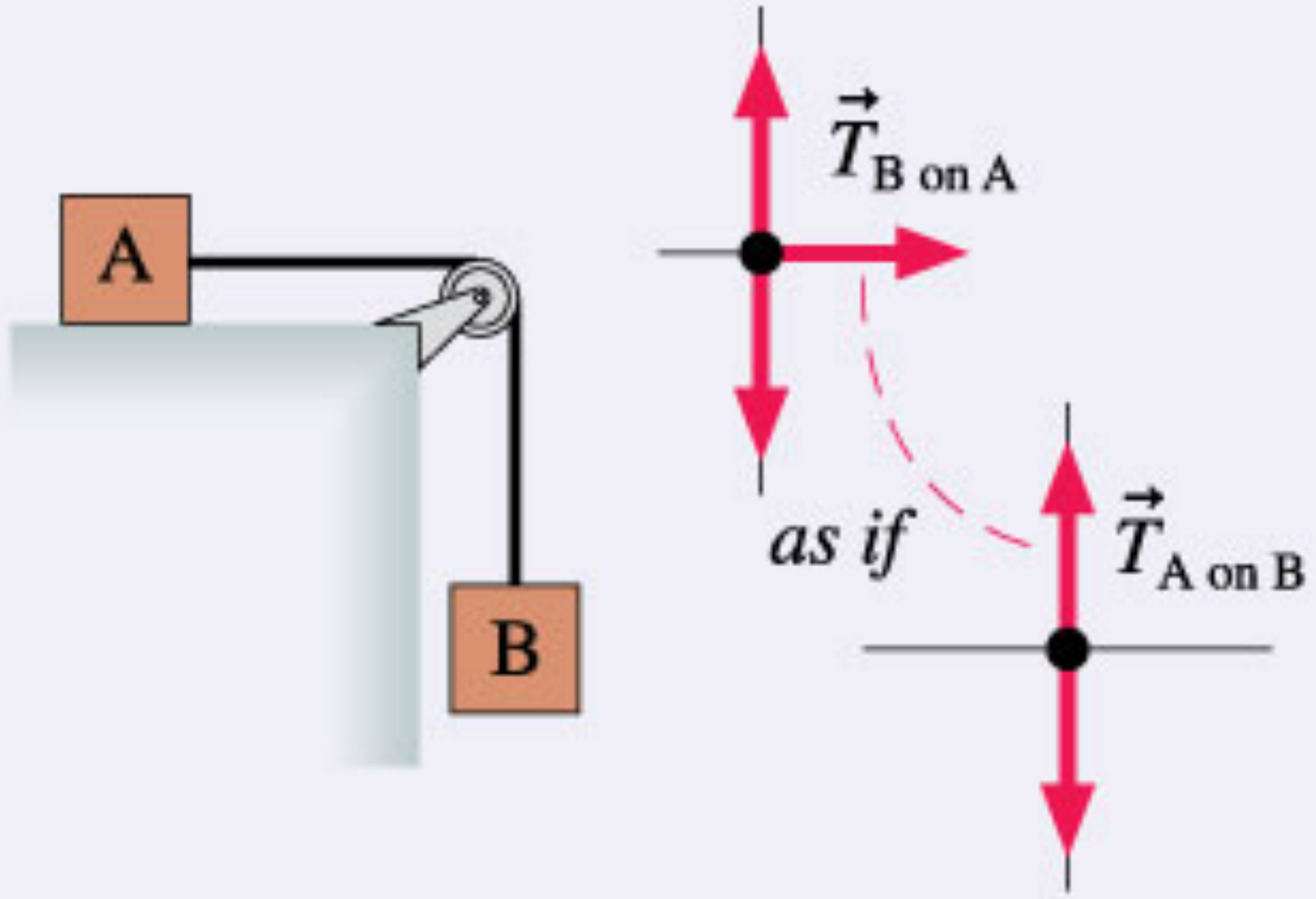
Strings and pulleys

The tension in a string or rope pulls in both directions. The tension is constant in a string if the string is:

- Massless, or
- In equilibrium

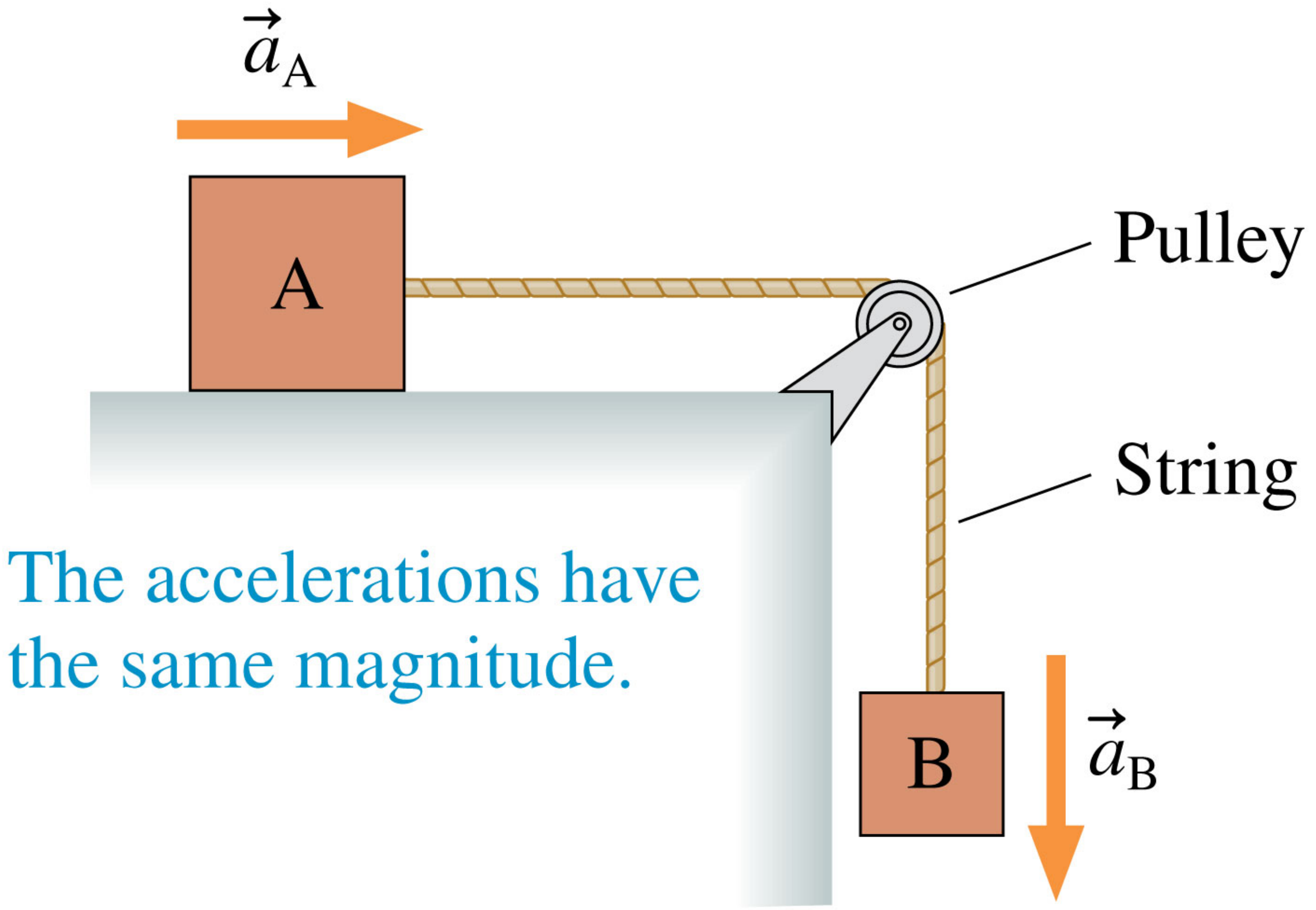
Objects connected by massless strings passing over massless, frictionless pulleys act *as if* they interact via an action/reaction pair of forces.





Acceleration Constraints

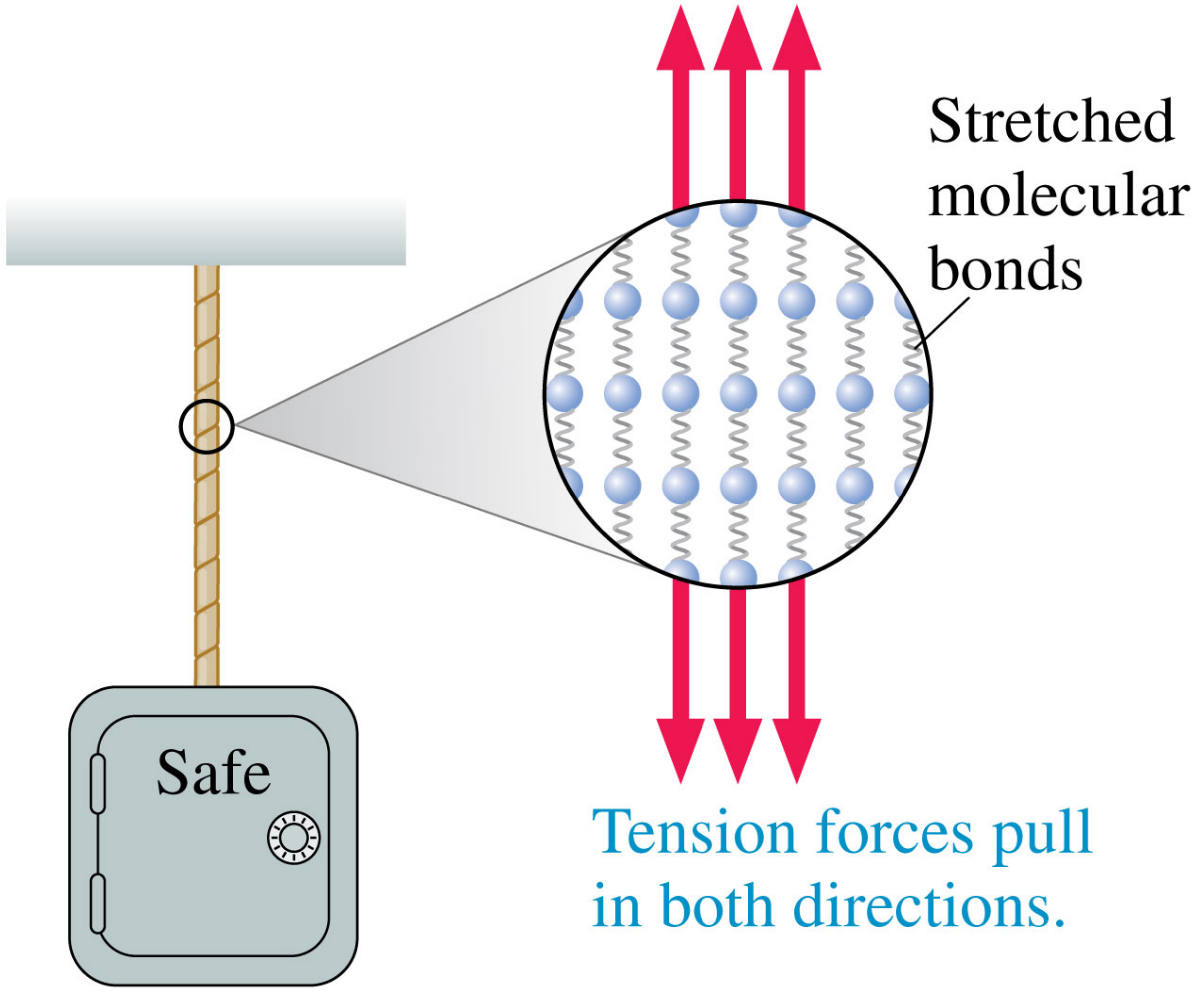
- Sometimes the acceleration of A and B may have different signs.
- Consider the blocks A and B in the figure.
- The string constrains the two objects to accelerate together.



- But, as A moves to the right in the $+x$ direction, B moves down in the $-y$ direction.
- In this case, the acceleration constraint is $a_{Ax} = -a_{By}$.

Tension Revisited

- The figure shows a heavy safe hanging from a rope, placing the rope under tension.
- Chapter 5 introduced an atomic-level model in which tension is due to the stretching of spring-like molecular bonds within the rope.

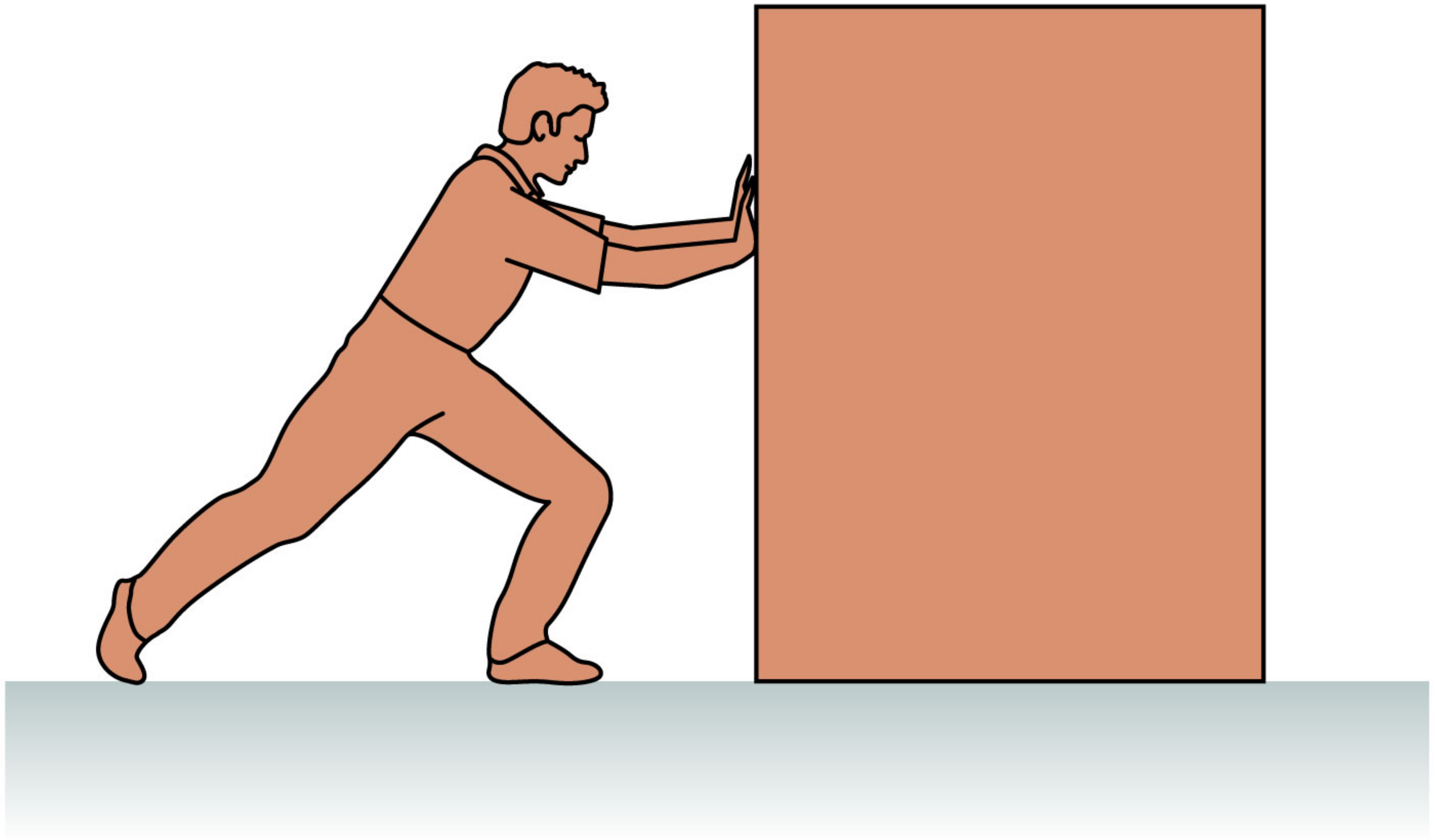


- Stretched springs exert pulling forces, and the combined pulling force of billions of stretched molecular springs in a string or rope is what we call **tension.**
- An important aspect of tension is that it pulls equally in both directions.

Example 7.1 Pushing a Crate

EXAMPLE 7.1 **Pushing a crate**

FIGURE 7.4 shows a person pushing a large crate across a rough surface. Identify all interactions, show them on an interaction diagram, then draw free-body diagrams of the person and the crate.

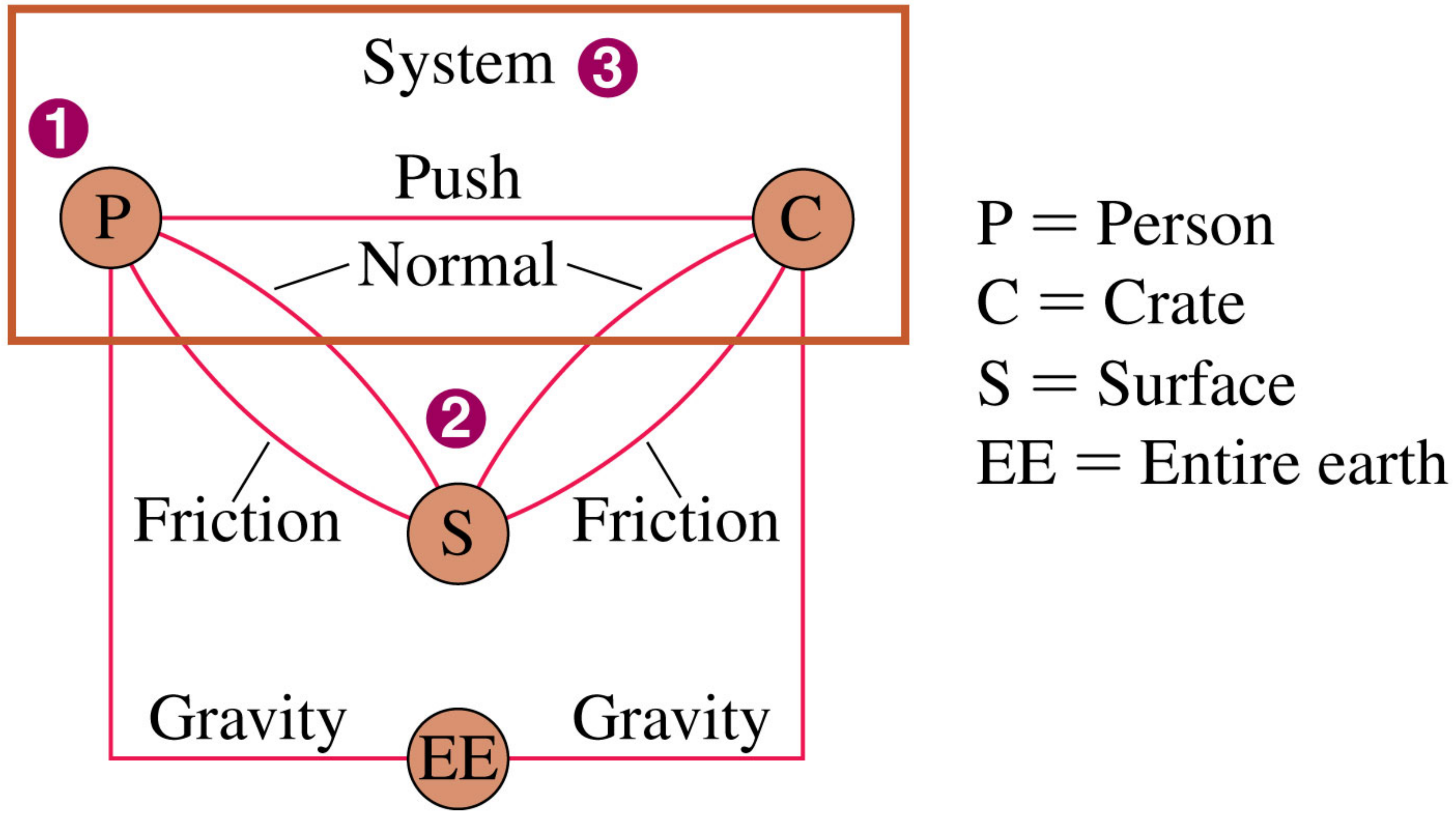


Example 7.1 Pushing a Crate

EXAMPLE 7.1 Pushing a crate

VISUALIZE

1. The person and crate are obvious objects, with a pushing force connecting them.
2. There are normal and friction contact forces between the person and crate and the surface. Also there is the long-range force of gravity between the person and crate and the entire earth.
3. The person and crate are the System; these are the objects whose motion we wish to analyze.

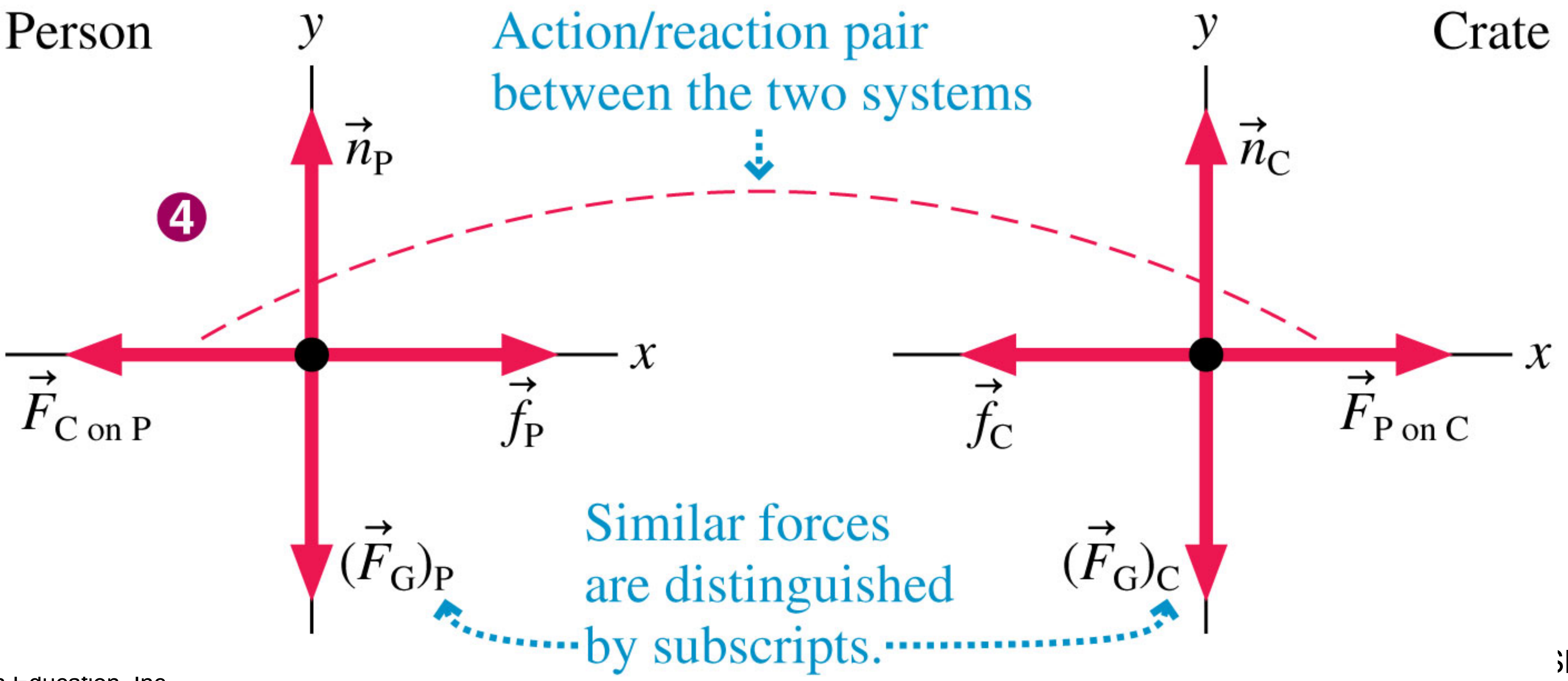


Example 7.1 Pushing a Crate

EXAMPLE 7.1 Pushing a crate

VISUALIZE

4. Below are the free-body diagrams of the person and the crate. For each, three forces are external forces. Subscripts label which object each force acts on. There is one internal interaction, labeled as an action/reaction pair.



Solving Interacting-Objects Problems

MODEL Identify which objects form the system.

VISUALIZE Draw a pictorial representation.

- Define symbols and coordinates.
- Identify acceleration constraints.
- Draw an interaction diagram.
- Draw a separate free-body diagram for each object.
- Connect action/reaction pairs with dashed lines.

SOLVE Write Newton's second law for each object.

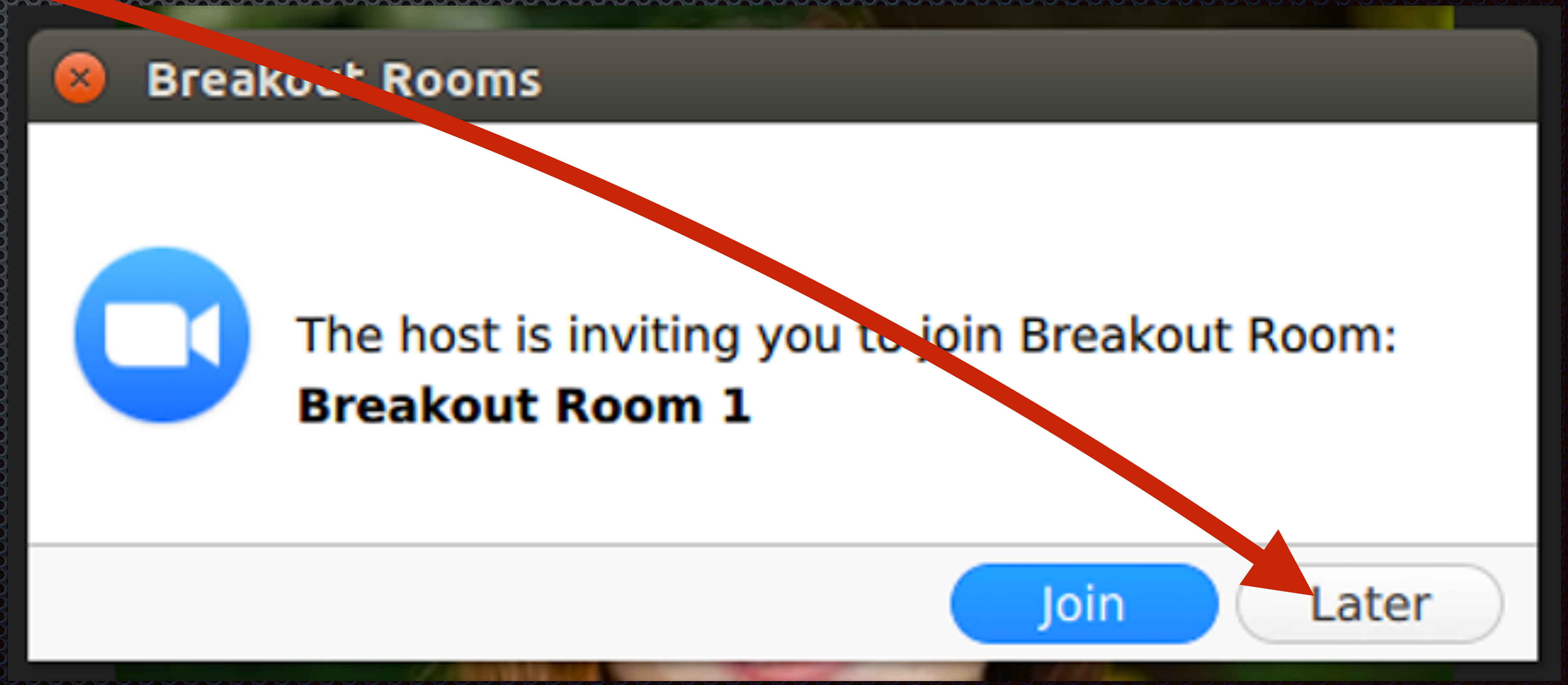
- Use the free-body diagrams.
- Equate the magnitudes of action/reaction pairs.
- Include acceleration constraints and friction.

ASSESS Is the result reasonable?

Chapter 7
Clicker Questions

Let’s try this: If we do breakout rooms, and you do not want to participate with your peers, that’s fine!

Stay in the main room and don’t join the room!!



QuickCheck 7.1

A mosquito runs head-on into a truck. Splat! Which is true during the collision?

A. The mosquito exerts more force on the truck than the truck exerts on the mosquito.
B. The truck exerts more force on the mosquito than the mosquito exerts on the truck.
C. The mosquito exerts the same force on the truck as the truck exerts on the mosquito.
D. The truck exerts a force on the mosquito but the mosquito does not exert a force on the truck.
E. The mosquito exerts a force on the truck but the truck does not exert a force on the mosquito.

QuickCheck 7.1

A mosquito runs head-on into a truck. Splat! Which is true during the collision?

A. The mosquito exerts more force on the truck than the truck exerts on the mosquito.

B. The truck exerts more force on the mosquito than the mosquito exerts on the truck.

✔ **C. The mosquito exerts the same force on the truck as the truck exerts on the mosquito.**

D. The truck exerts a force on the mosquito but the mosquito does not exert a force on the truck.

E. The mosquito exerts a force on the truck but the truck does not exert a force on the mosquito.

QuickCheck 7.2

A mosquito runs head-on into a truck. Which is true during the collision?

A. The magnitude of the mosquito's acceleration is larger than that of the truck.
B. The magnitude of the truck's acceleration is larger than that of the mosquito.
C. The magnitude of the mosquito's acceleration is the same as that of the truck.
D. The truck accelerates but the mosquito does not.
E. The mosquito accelerates but the truck does not.

QuickCheck 7.2

A mosquito runs head-on into a truck. Which is true during the collision?

A. **The magnitude of the mosquito's acceleration is larger than that of the truck.**
B. The magnitude of the truck's acceleration is larger than that of the mosquito.
C. The magnitude of the mosquito's acceleration is the same as that of the truck.
D. The truck accelerates but the mosquito does not.
E. The mosquito accelerates but the truck does not.

Same for both

Newton's second law: $a = \dfrac{F}{m}$

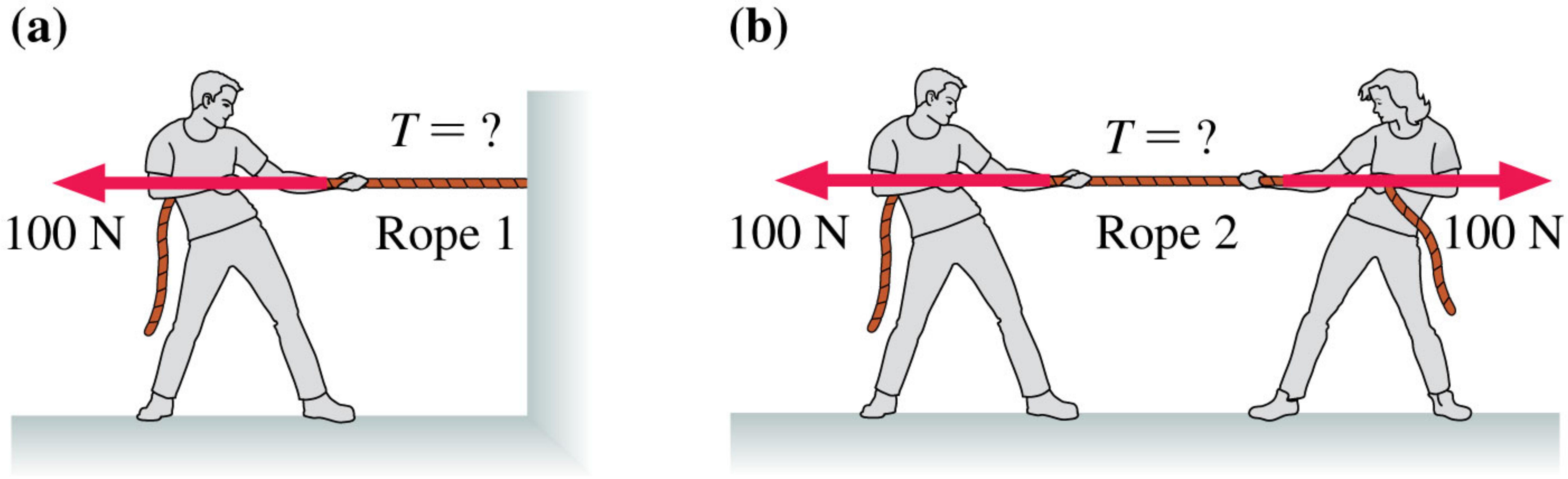
Huge difference

Don't confuse cause and effect! The same force can have very different effects.

Example 7.5 Pulling a Rope

EXAMPLE 7.5 | **Pulling a rope**

FIGURE 7.18a shows a student pulling horizontally with a 100 N force on a rope that is attached to a wall. In **FIGURE 7.18b**, two students in a tug-of-war pull on opposite ends of a rope with 100 N each. Is the tension in the second rope larger than, smaller than, or the same as that in the first rope?



Example 7.5 Pulling a Rope

EXAMPLE 7.5 **Pulling a rope**

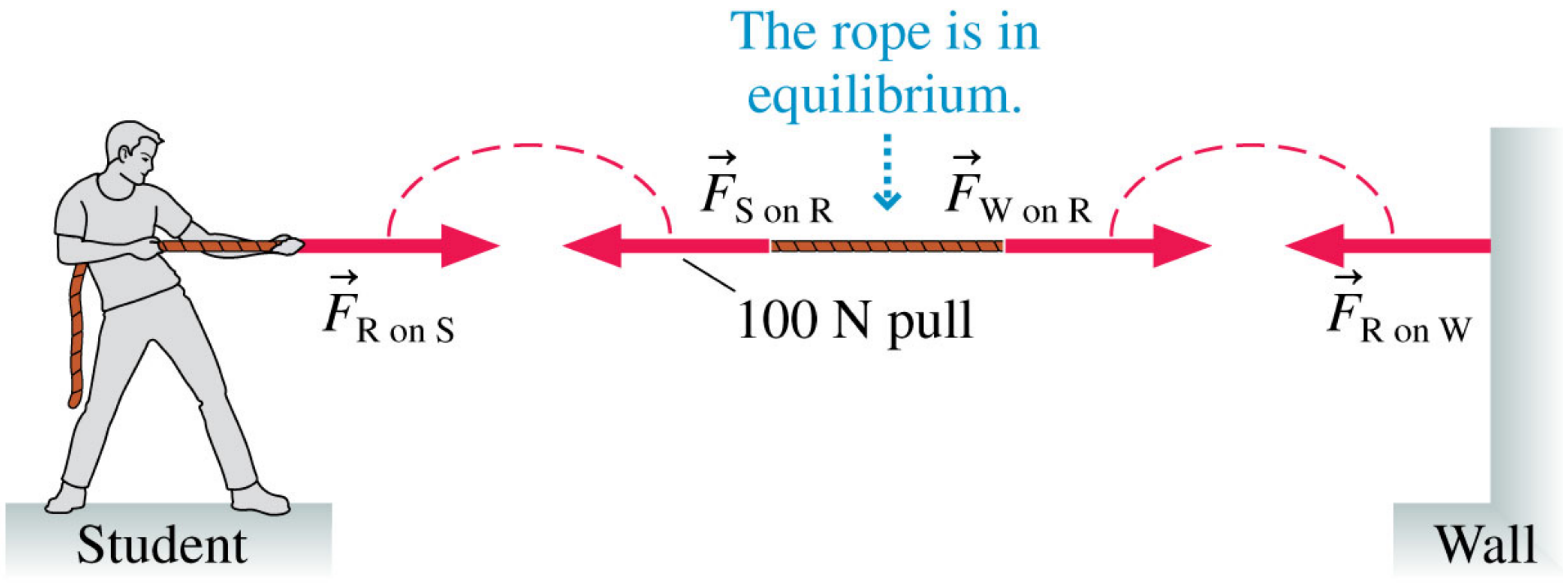
SOLVE Surely pulling on a rope from both ends causes more tension than pulling on one end. Right? Before jumping to conclusions, let's analyze

FIGURE 7.19a shows the first student, the rope, and the wall as separate, interacting objects. Force $\vec{F}_{\text{S on R}}$ is the student pulling on the rope, so it has magnitude 100 N. Forces $\vec{F}_{\text{S on R}}$ and $\vec{F}_{\text{R on S}}$ are an action/reaction pair and must have equal magnitudes. Similarly for forces $\vec{F}_{\text{W on R}}$ and $\vec{F}_{\text{R on W}}$. Finally, because the rope is in static equilibrium, *force* $\vec{F}_{\text{W on R}}$ *has to balance force* $\vec{F}_{\text{S on R}}$. Thus

$$F_{\text{R on W}} = F_{\text{W on R}} = F_{\text{S on R}} = F_{\text{R on S}} = 100 \text{ N}$$

The first and third equalities are Newton's third law; the second equality is Newton's first law for the rope.

Forces $\vec{F}_{\text{R on S}}$ and $\vec{F}_{\text{R on W}}$ are the pulling forces exerted by the rope and are what we *mean* by "the tension in the rope." Thus the tension in the first rope is 100 N.



Example 7.5 Pulling a Rope

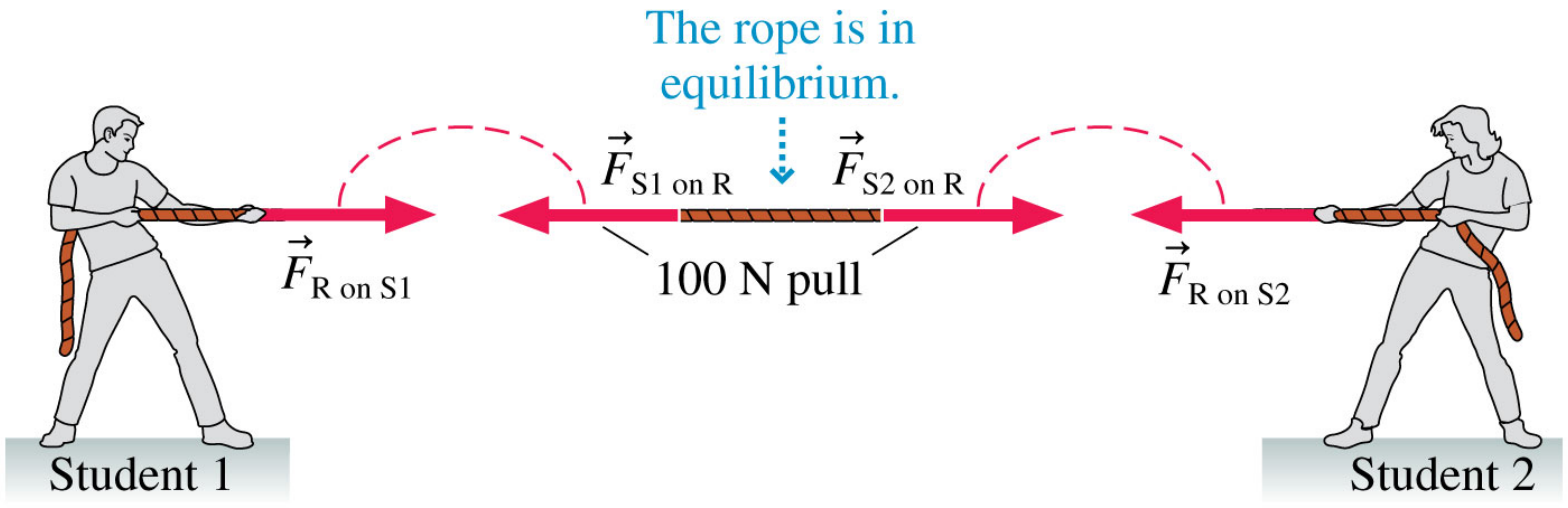
EXAMPLE 7.5 | **Pulling a rope**

SOLVE **FIGURE 7.19b** repeats the analysis for the rope pulled by two students. Each student pulls with 100 N, so $F_{\text{S1 on R}} = 100$ N and $F_{\text{S2 on R}} = 100$ N. Just as before, there are two action/reaction pairs rope is in static equilibrium. Thus

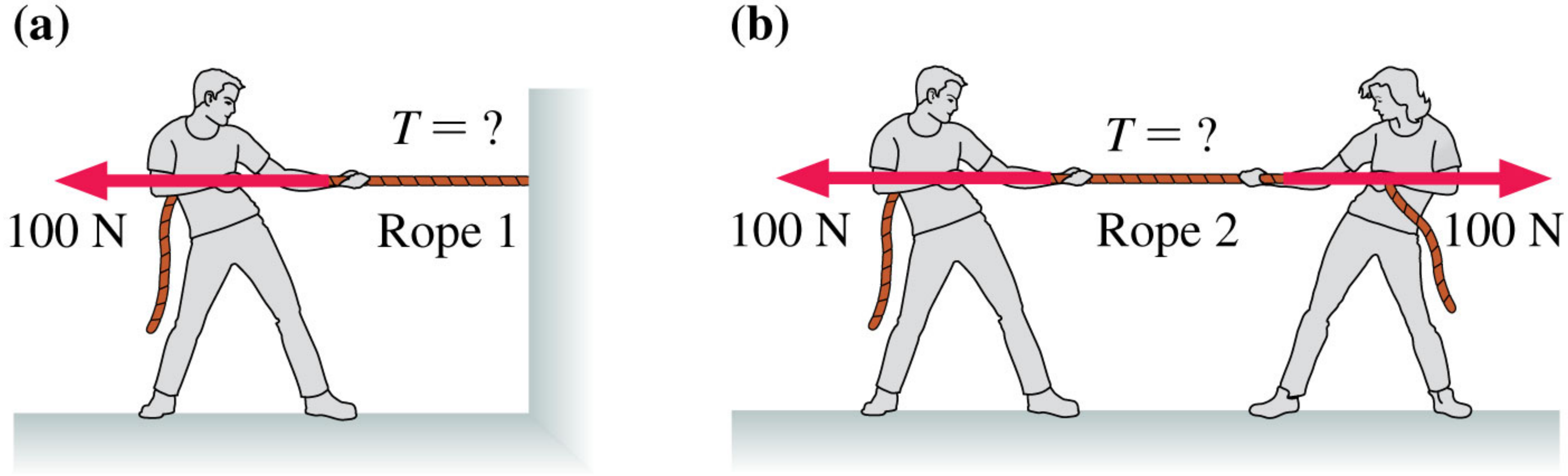
$$F_{\text{R on S2}} = F_{\text{S2 on R}} = F_{\text{S1 on R}} = F_{\text{R on S1}} = 100 \text{ N}$$

The tension in the rope—the pulling forces $\vec{F}_{\text{R on S1}}$ and $\vec{F}_{\text{R on S2}}$—is still 100 N!

You may have *assumed* that the student on the right in Figure 7.18b is doing something to the rope that the wall in Figure 7.18a does not do. But our analysis finds that the wall, just like the student, pulls to the right with 100 N. The rope doesn't care whether it's pulled by a wall or a hand. It experiences the same forces in both cases, so the rope's tension is the same in both.



Example 7.5 Pulling a Rope



The rope's tension is the same in both situations.

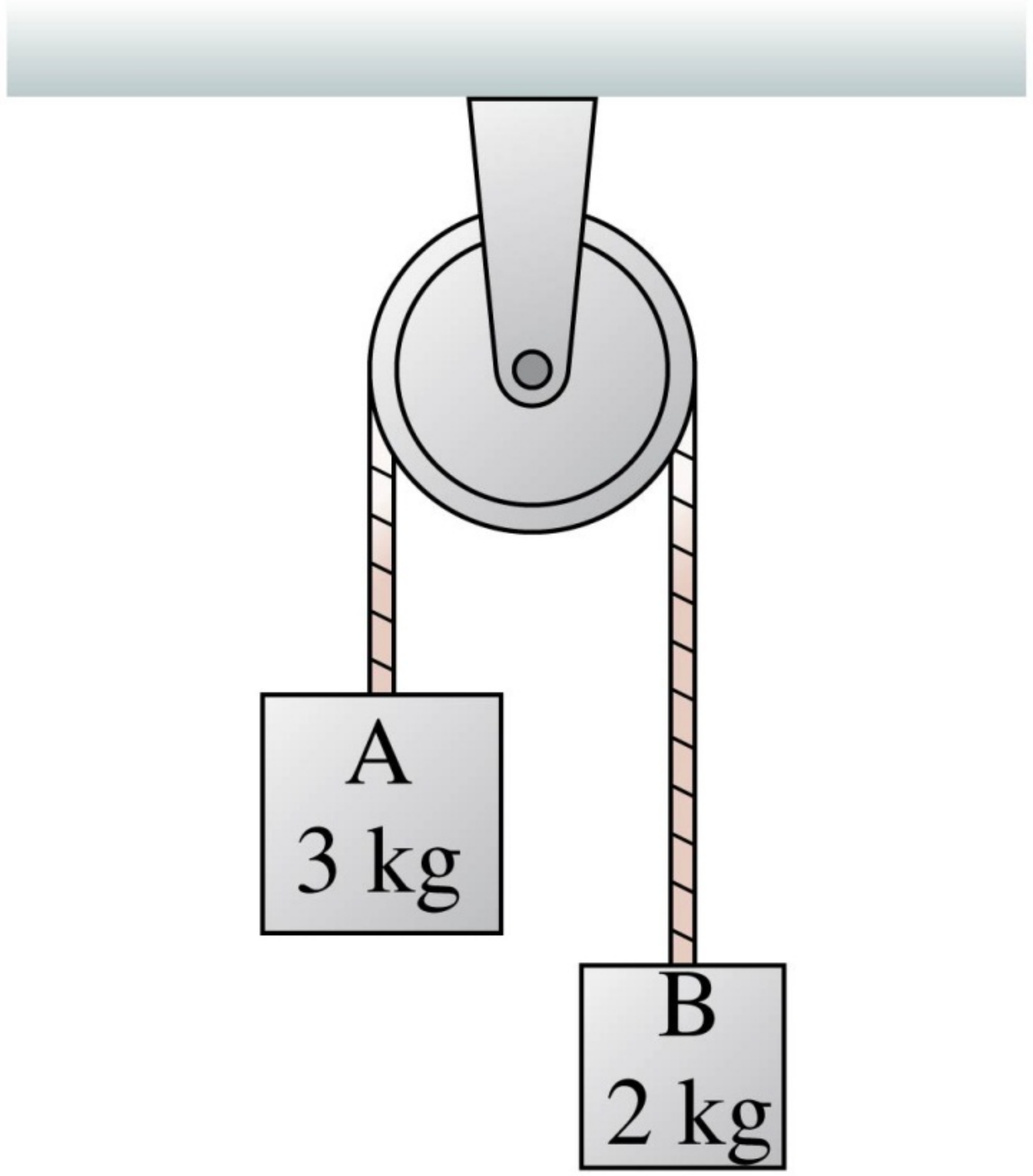
EXAMPLE 7.5 **Pulling a rope**

ASSESS Ropes and strings exert forces at *both* ends. The force with which they pull—and thus the force pulling on them at each end—*is* the tension in the rope. Tension is not the sum of the pulling forces.

QuickCheck 7.9

The acceleration constraint here is

A. $a_{Ay} = a_{By}$
B. $-a_{Ay} = -a_{By}$
C. $a_{Ay} = -a_{By}$
D. $a_{By} = -a_{Ay}$
E. Either C or D.

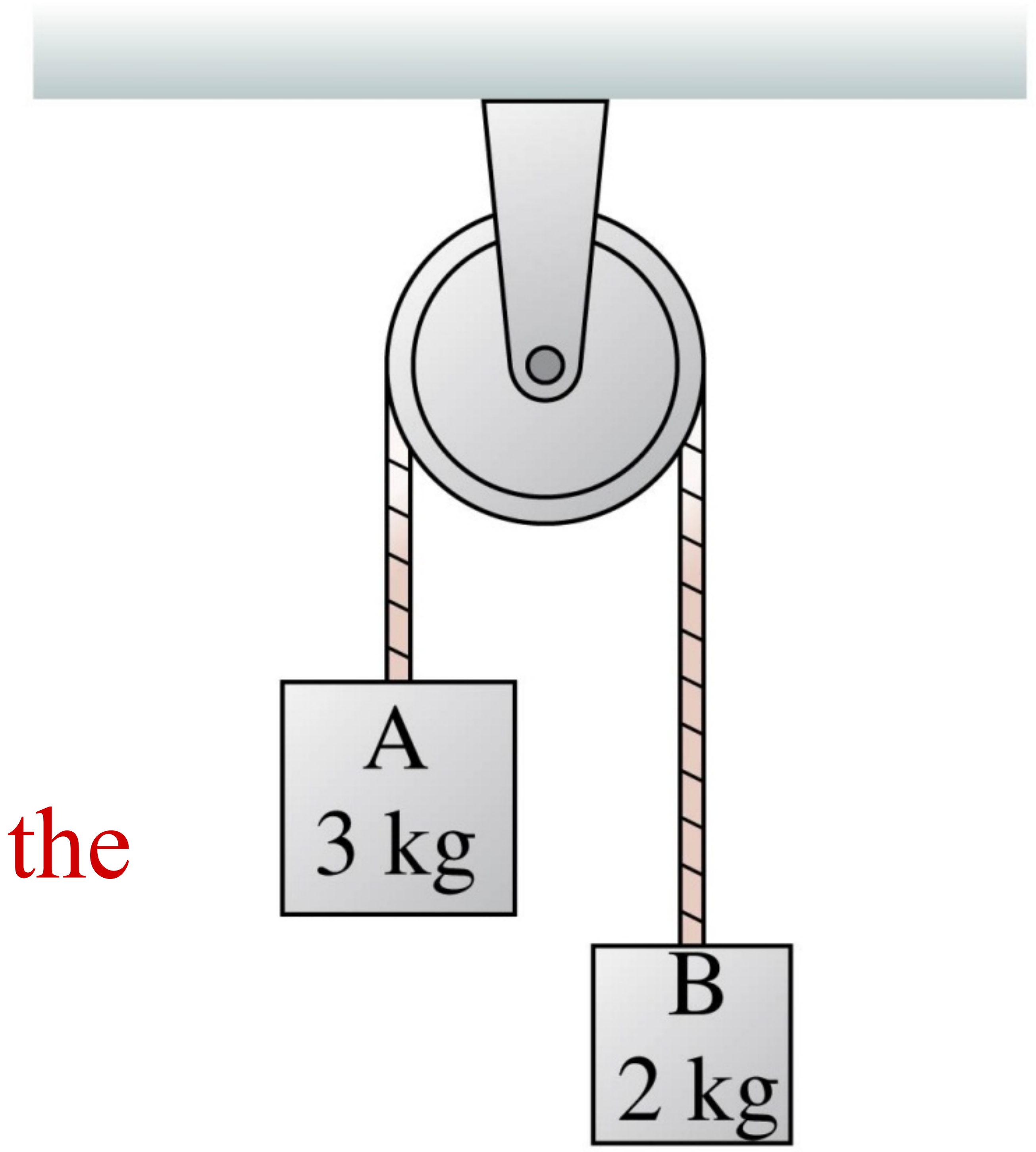


QuickCheck 7.9

The acceleration constraint here is

A. $a_{Ay} = a_{By}$
B. $-a_{Ay} = -a_{By}$
C. $a_{Ay} = -a_{By}$
D. $a_{By} = -a_{Ay}$
✔ E. **Either C or D.**

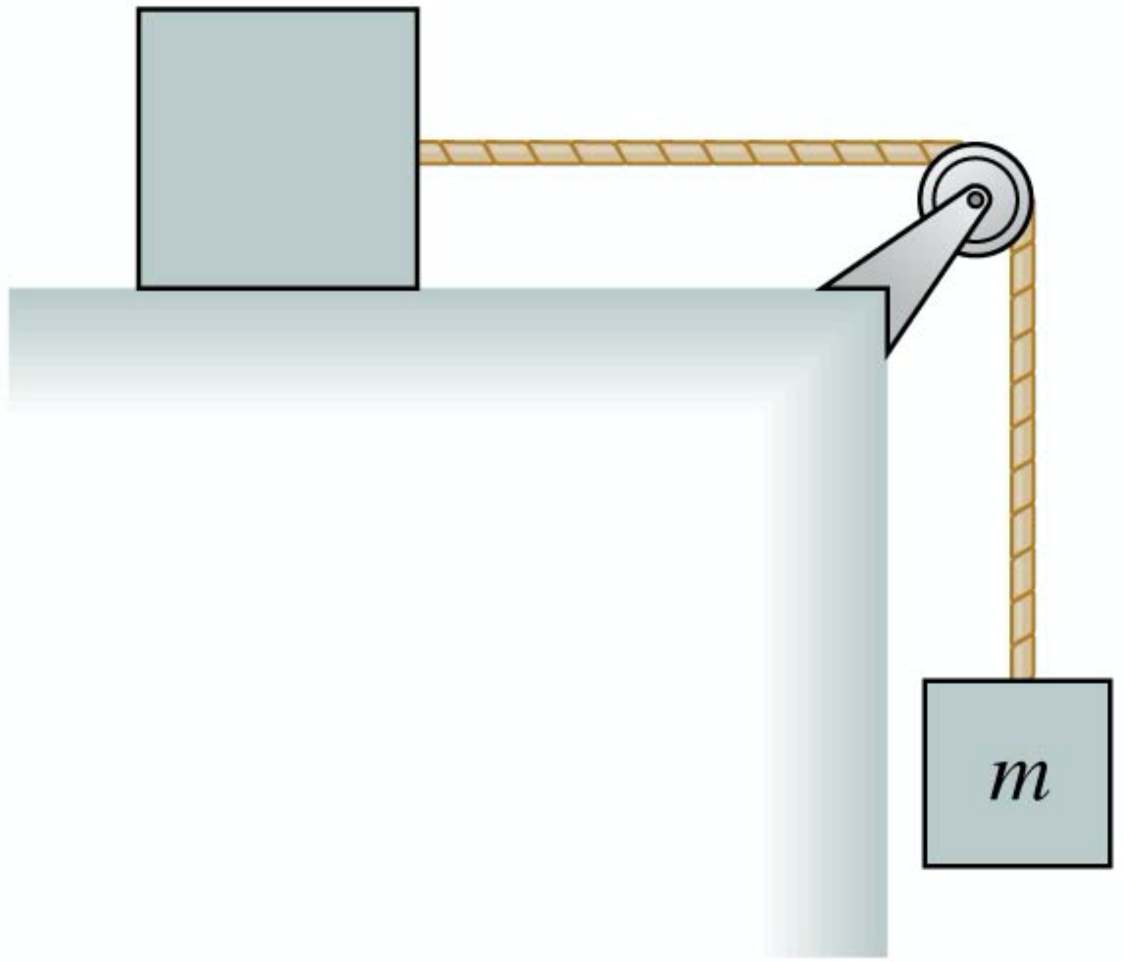
Either says that the acceleration vectors point in opposite directions.



QuickCheck 7.10

The top block is accelerated across a <u>frictionless</u> table by the falling mass m. The string is massless, and the pulley is both massless and frictionless. The tension in the string is

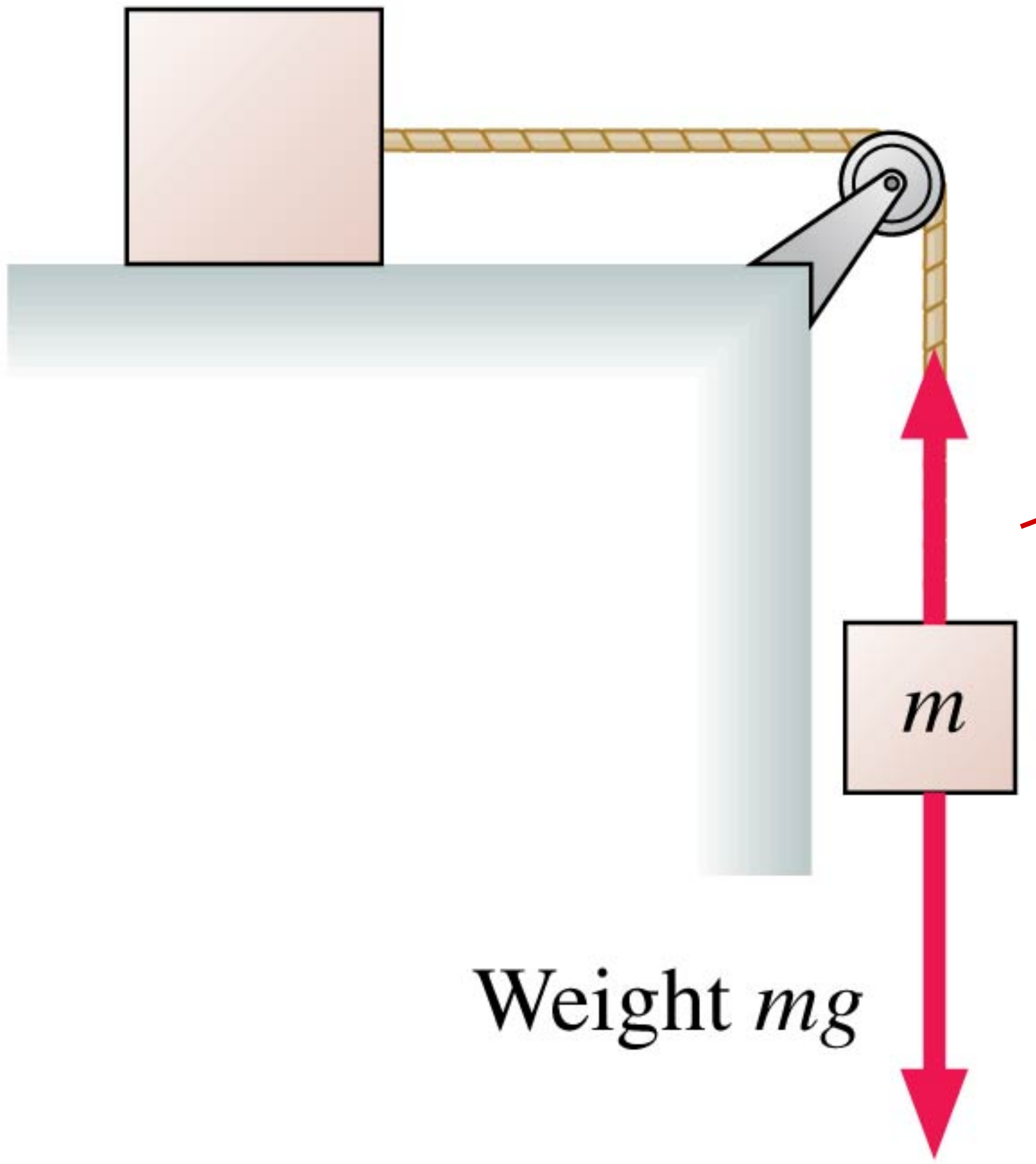
A. $T < mg$
B. $T = mg$
C. $T > mg$



QuickCheck 7.10

The top block is accelerated across a frictionless table by the falling mass m. The string is massless, and the pulley is both massless and frictionless. The tension in the string is

✔ **A.** $\boldsymbol{T < mg}$
B. $T = mg$
C. $T > mg$

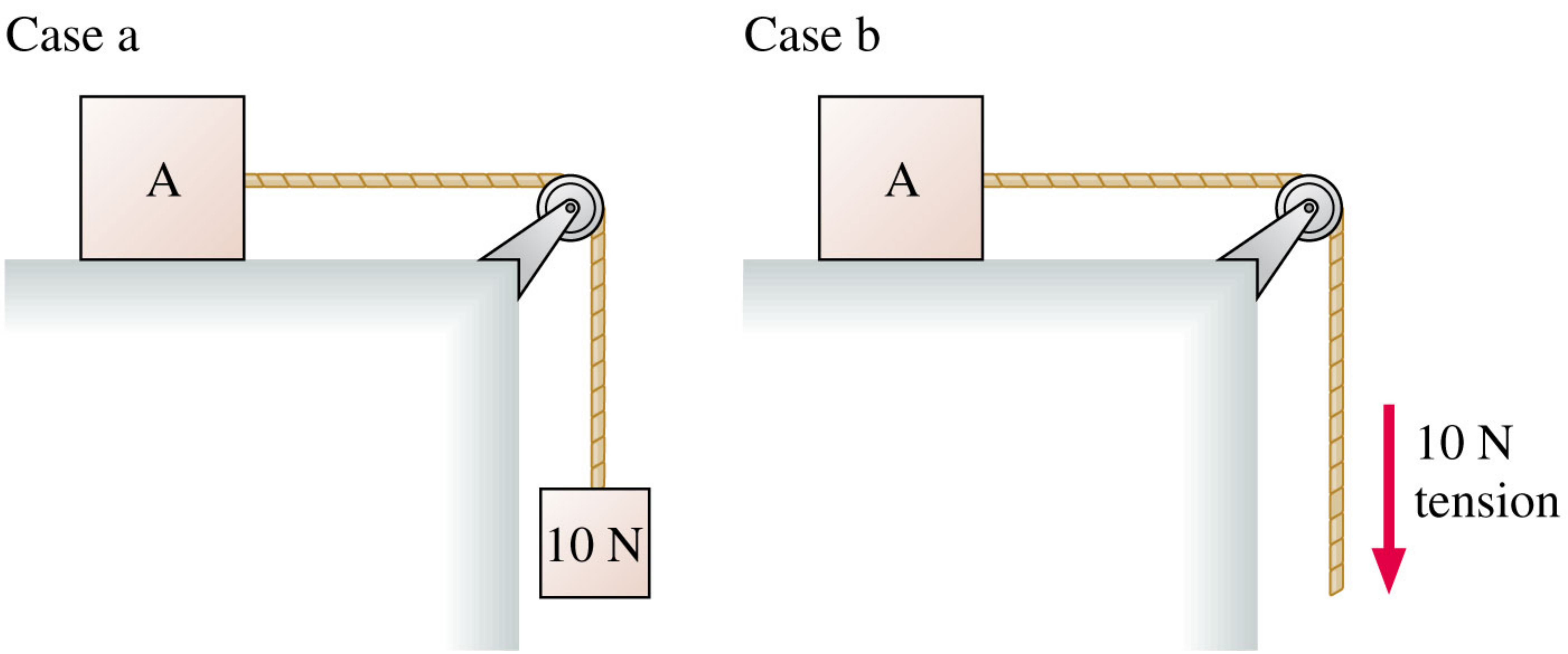


Tension has to be less than mg for the block to have a downward acceleration.

QuickCheck 7.11

Block A is accelerated across a frictionless table. The string is massless, and the pulley is both massless and frictionless. Which is true?

A. Block A accelerates faster in case a than in case b.
B. Block A has the same acceleration in case a and case b.
C. Block A accelerates slower in case a than in case b.



QuickCheck 7.11

Block A is accelerated across a frictionless table. The string is massless, and the pulley is both massless and frictionless. Which is true?

A. Block A accelerates faster in case a than in case b.
B. Block A has the same acceleration in case a and case b.
C. **Block A accelerates slower in case a than in case b.**