Physics 111 - Class 5B
Forces II

October 5, 2022

Class Outline

- Logistics / Announcements
- Introduction to Chapter 5
- Clicker Questions
- Mid-term Feedback
- Worked Problems

Logistics/Announcements

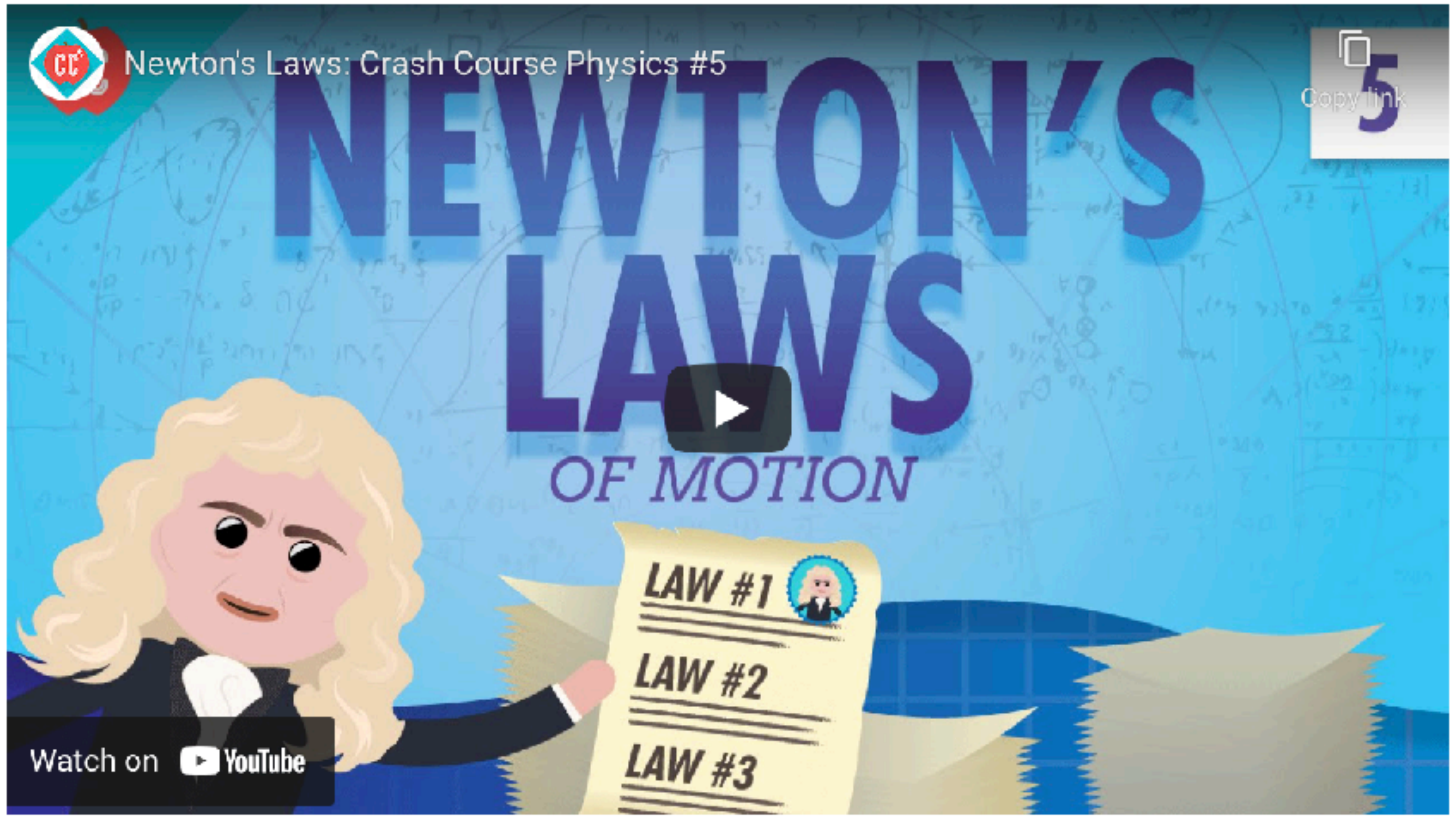
- Lab this week
- HW5 due this week on Thursday at 6 PM
- Learning Log 5 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Test 2 available this week (Chapters 3 & 4)
  - Test will be on Friday during class!
  - Bus Strike Updates...

Physics 111

Search this book...

Content Summary from Crash Course Physics

Newton's Laws



Checklist of items

- [ ] Video 1
- [ ] Video 2
- [ ] Video 3
- [ ] Video 4
- [ ] Video 5
- [ ] Video 6
- [ ] Video 7
- [ ] Video 8
- [ ] Video 9
- [ ] Video 10
- [ ] Video 11
- [ ] Video 12

Required Videos

1. Introduction to Inertia and Inertial Mass

Figure 5.1 The Golden Gate Bridge, one of the greatest works of modern engineering, was the longest suspension bridge in the world in the year it opened, 1937. It is still among the 10 longest suspension bridges as of this writing. In designing and building a bridge, what physics must we consider? What forces act on the bridge? What forces keep the bridge from falling? How do the towers, cables, and ground interact to maintain stability?

Chapter Outline

Wednesday's Class

5.3 Newton's Second Law
5.5 Newton's Third Law
5.6 Common Forces

Newton's First Law

NEWTON'S FIRST LAW OF MOTION

A body at rest remains at rest or, if in motion, remains in motion at constant velocity unless acted on by a net external force.

Note the repeated use of the verb "remains." We can think of this law as preserving the status quo of motion. Also note the expression "constant velocity;" this means that the object maintains a path along a straight line, since neither the magnitude nor the direction of the velocity vector changes. We can use Figure 5.7 to consider the two parts of Newton's first law.

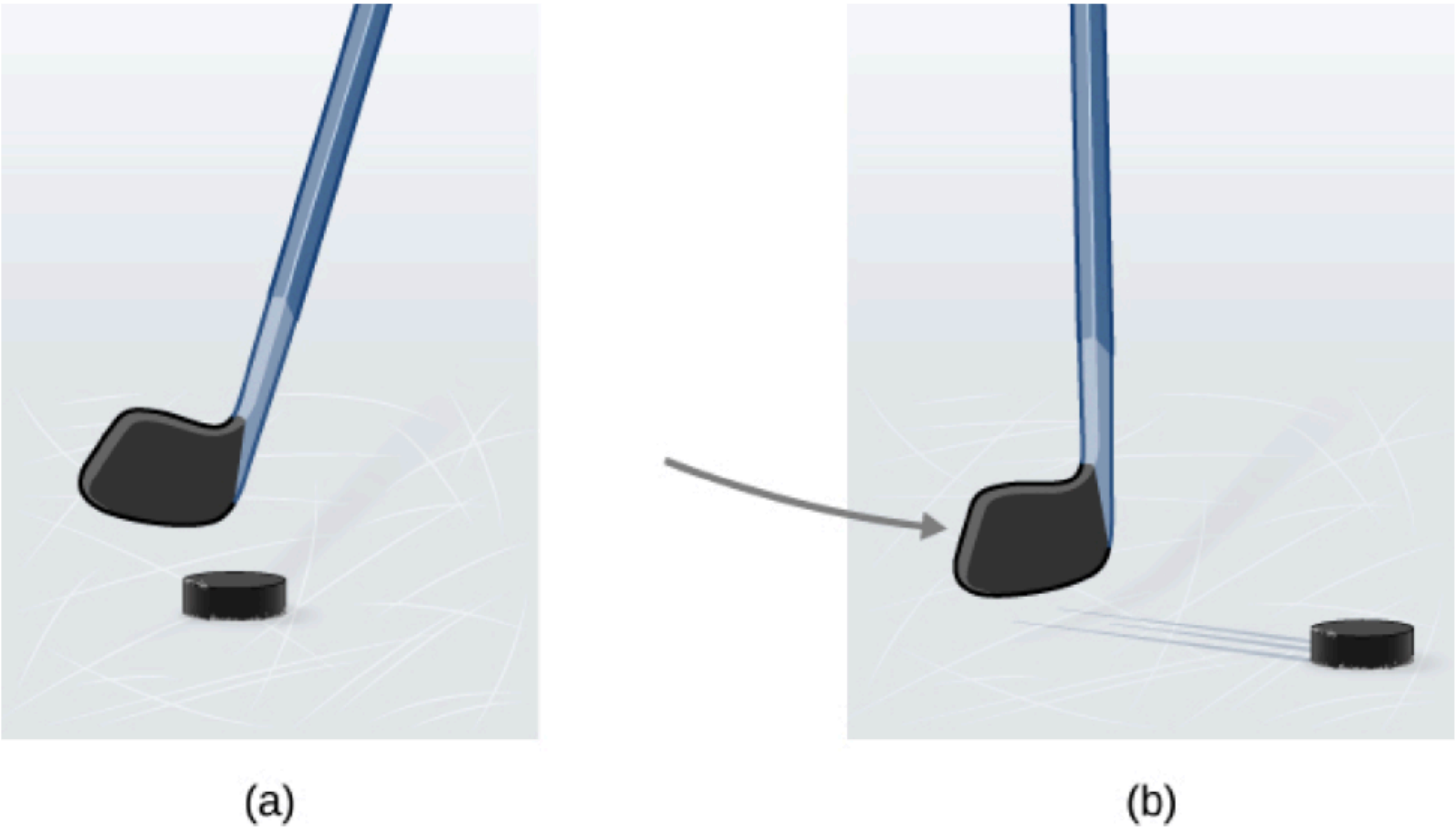


Figure 5.7 (a) A hockey puck is shown at rest; it remains at rest until an outside force such as a hockey stick changes its state of rest; (b) a hockey puck is shown in motion; it continues in motion in a straight line until an outside force causes it to change its state of motion. Although it is slick, an ice surface provides some friction that slows the puck.

Applying Newton's First Law

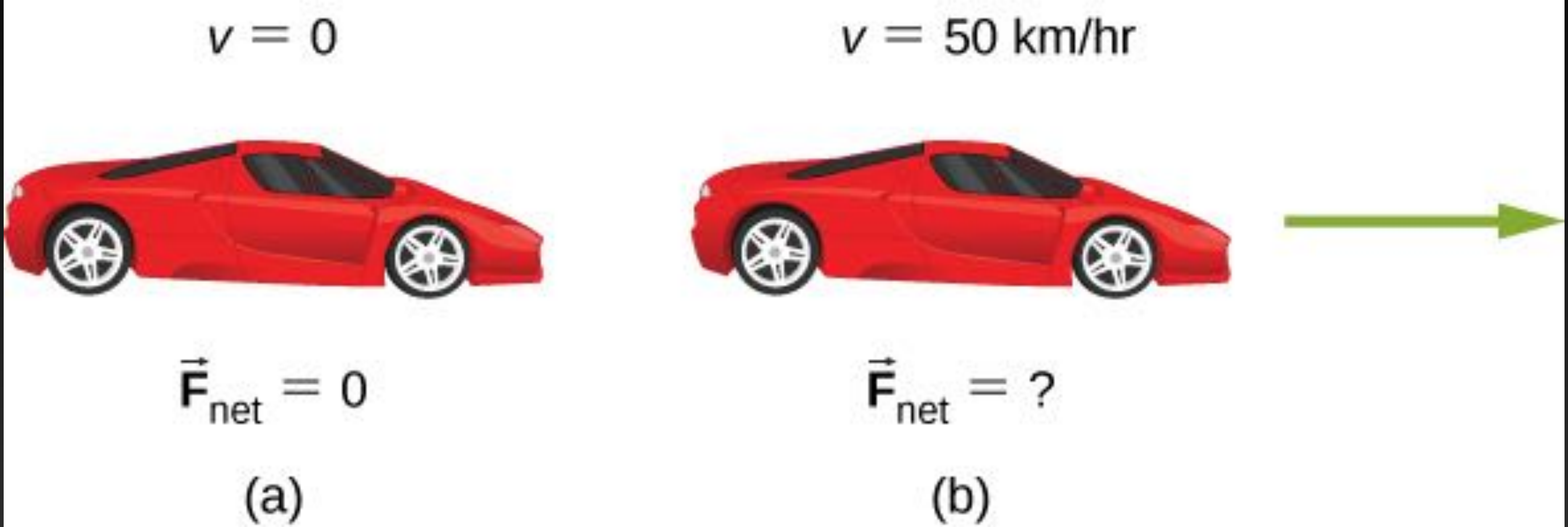


Figure 5.9
(a) A car is parked and has a velocity of 0 km/hr. What is the net force on this car?
(b) A car is moving at a constant velocity of 50 km/hr. What is the net force on the car?

Applying Newton’s First Law

If velocity of an object is constant, it means acceleration is 0 !!

If acceleration of an object is 0, it does NOT mean velocity is 0 !!

Newton's Second Law

NEWTON'S SECOND LAW OF MOTION

The acceleration of a system is directly proportional to and in the same direction as the net external force acting on the system and is inversely proportion to its mass. In equation form, Newton's second law is

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

where $\vec{\mathbf{a}}$ is the acceleration, $\vec{\mathbf{F}}_{\text{net}}$ is the net force, and m is the mass. This is often written in the more familiar form

$$\vec{\mathbf{F}}_{\text{net}} = \sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}, \tag{5.3}$$

but the first equation gives more insight into what Newton's second law means. When only the magnitude of force and acceleration are considered, this equation can be written in the simpler scalar form:

$$F_{\text{net}} = ma. \tag{5.4}$$

Applying Newton's Second Law

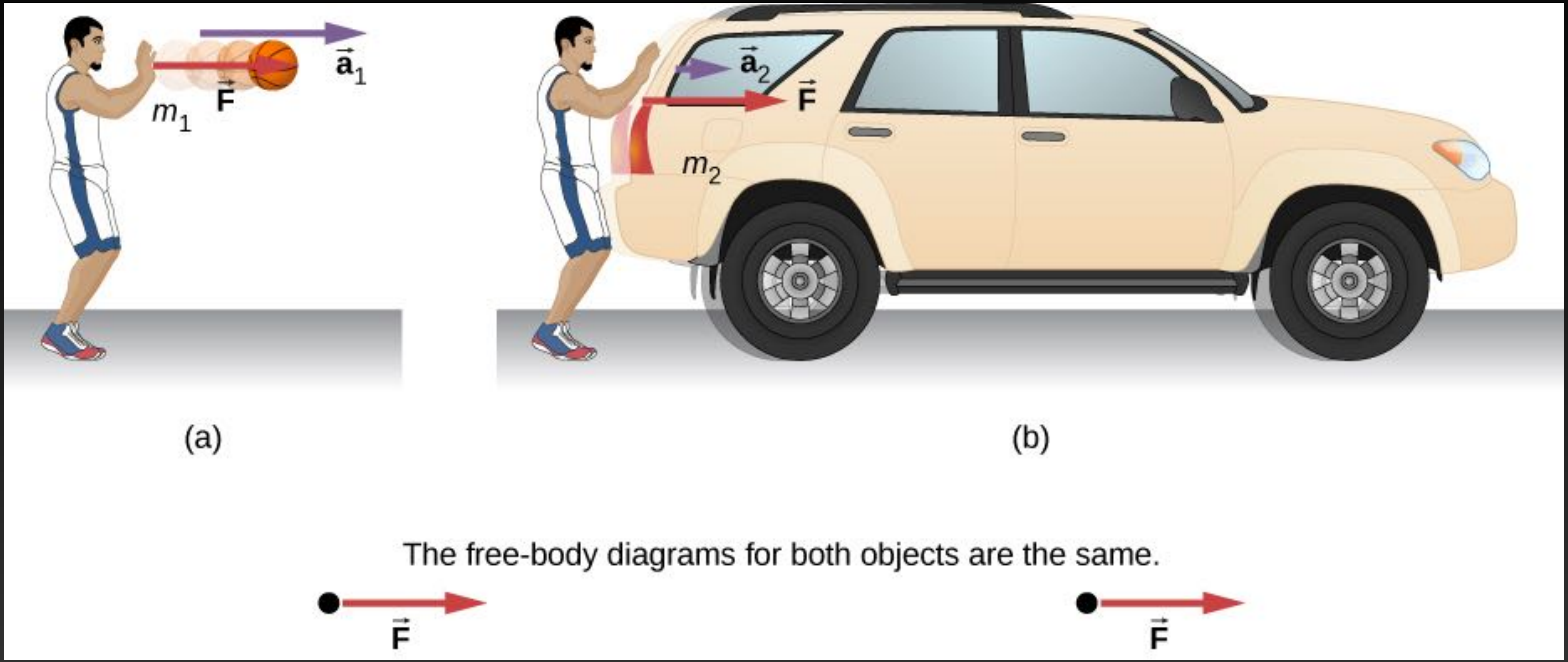


Figure 5.11

(a) A player applies a force **F** to a basketball of mass m_1

(b) The same player then applies a force of the same magnitude as **F** to a a car of mass m2 ($m_2 = 4000m_1$)

Applying Newton's Second Law

Which Force Is Bigger?

(a) The car shown in Figure 5.13 is moving at a constant speed. Which force is bigger, $\vec{\mathbf{F}}_{\text{friction}}$ or $\vec{\mathbf{F}}_{\text{drag}}$? Explain.

(b) The same car is now accelerating to the right. Which force is bigger, $\vec{\mathbf{F}}_{\text{friction}}$ or $\vec{\mathbf{F}}_{\text{drag}}$? Explain.

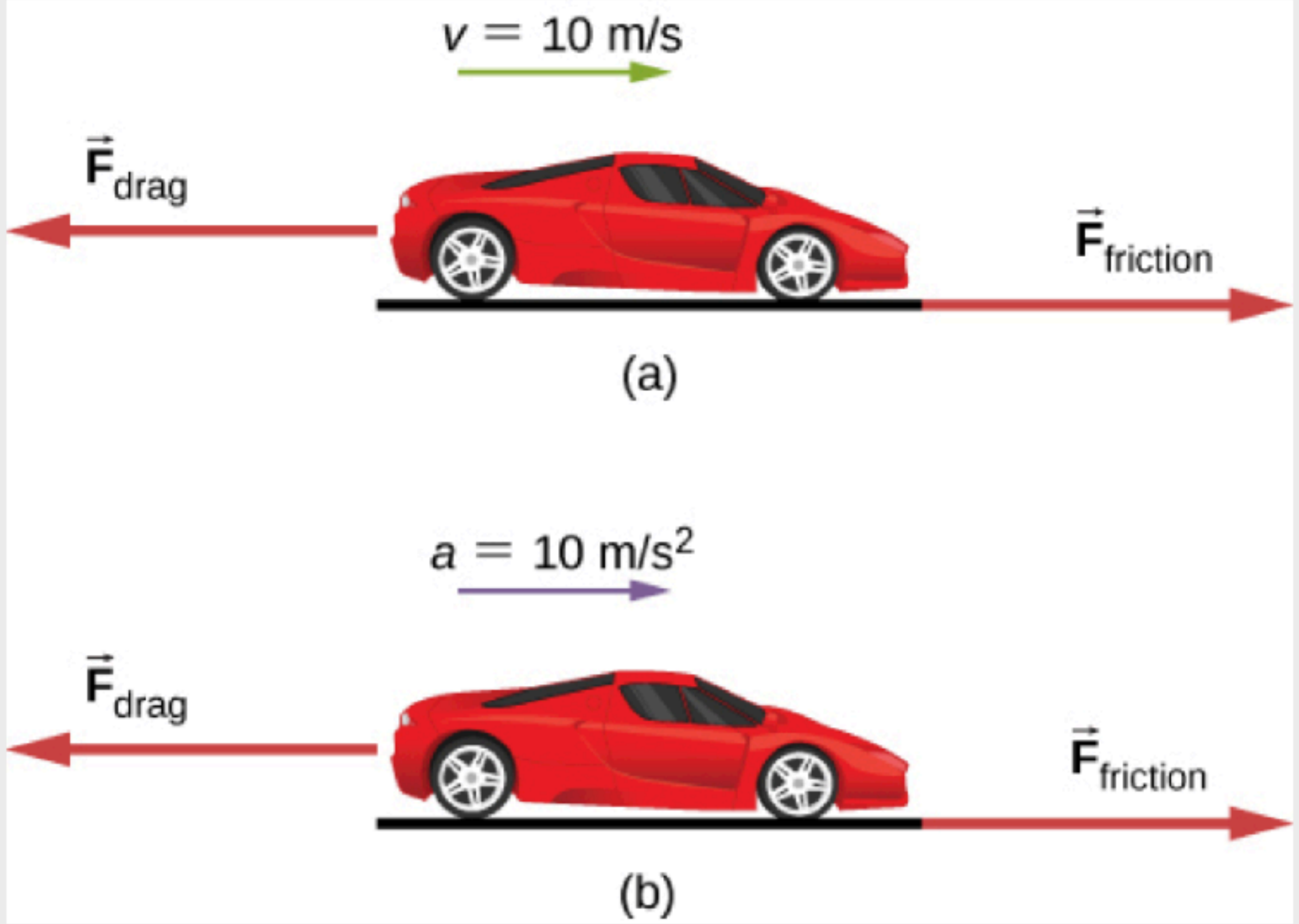


Figure 5.13 A car is shown (a) moving at constant speed and (b) accelerating. How do the forces acting on the car compare in each case? (a) What does the knowledge that the car is moving at constant velocity tell us about the net horizontal force on the car compared to the friction force? (b) What does the knowledge that the car is accelerating tell us about the horizontal force on the car compared to the friction force?

Applying Newton's Second Law

Which Force Is Bigger?

(a) The car shown in Figure 5.13 is moving at a constant speed. Which force is bigger, $\vec{\mathbf{F}}_{\text{friction}}$ or $\vec{\mathbf{F}}_{\text{drag}}$? Explain.

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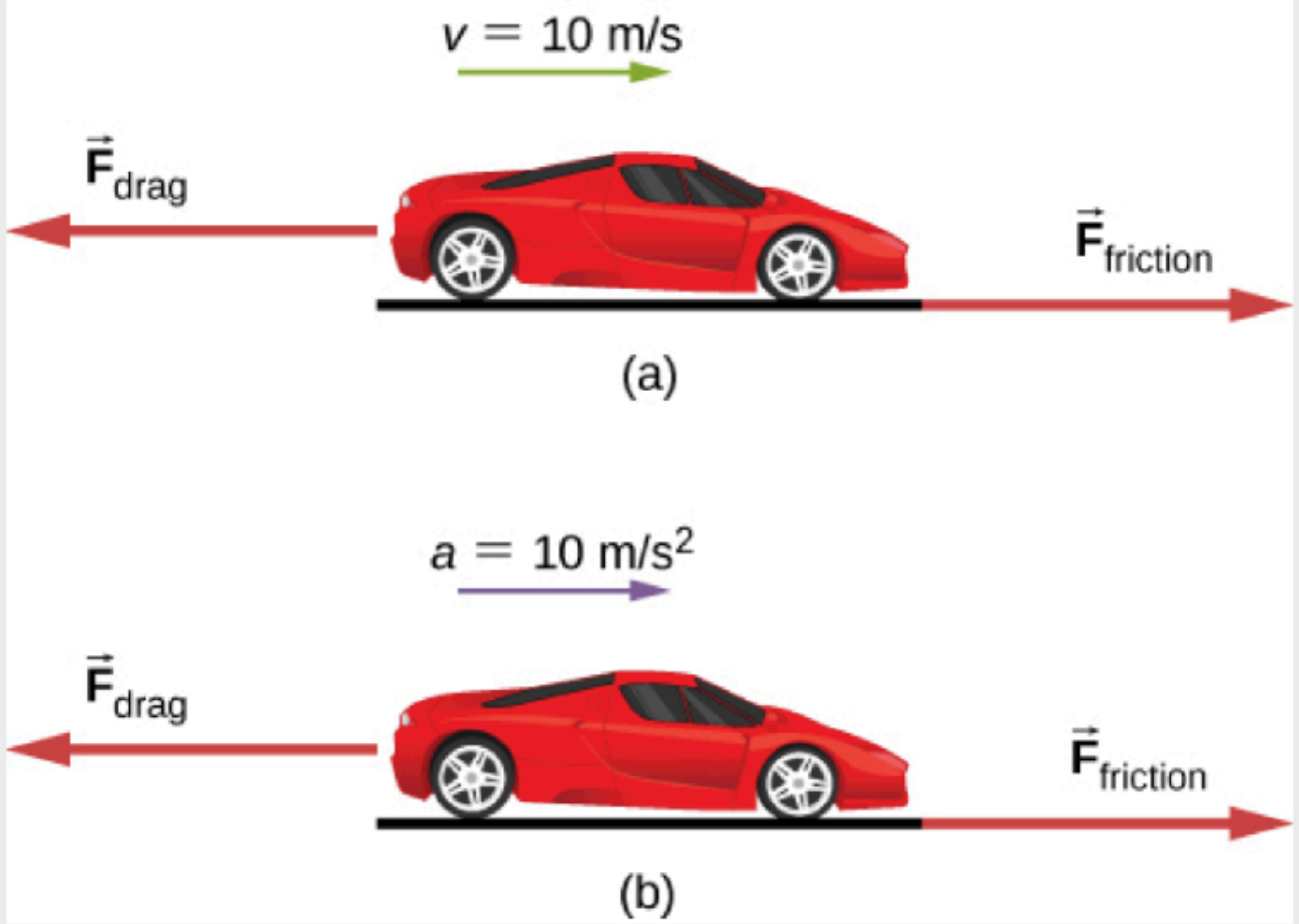

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Strategy

We must consider Newton's first and second laws to analyze the situation. We need to decide which law applies; this, in turn, will tell us about the relationship between the forces.

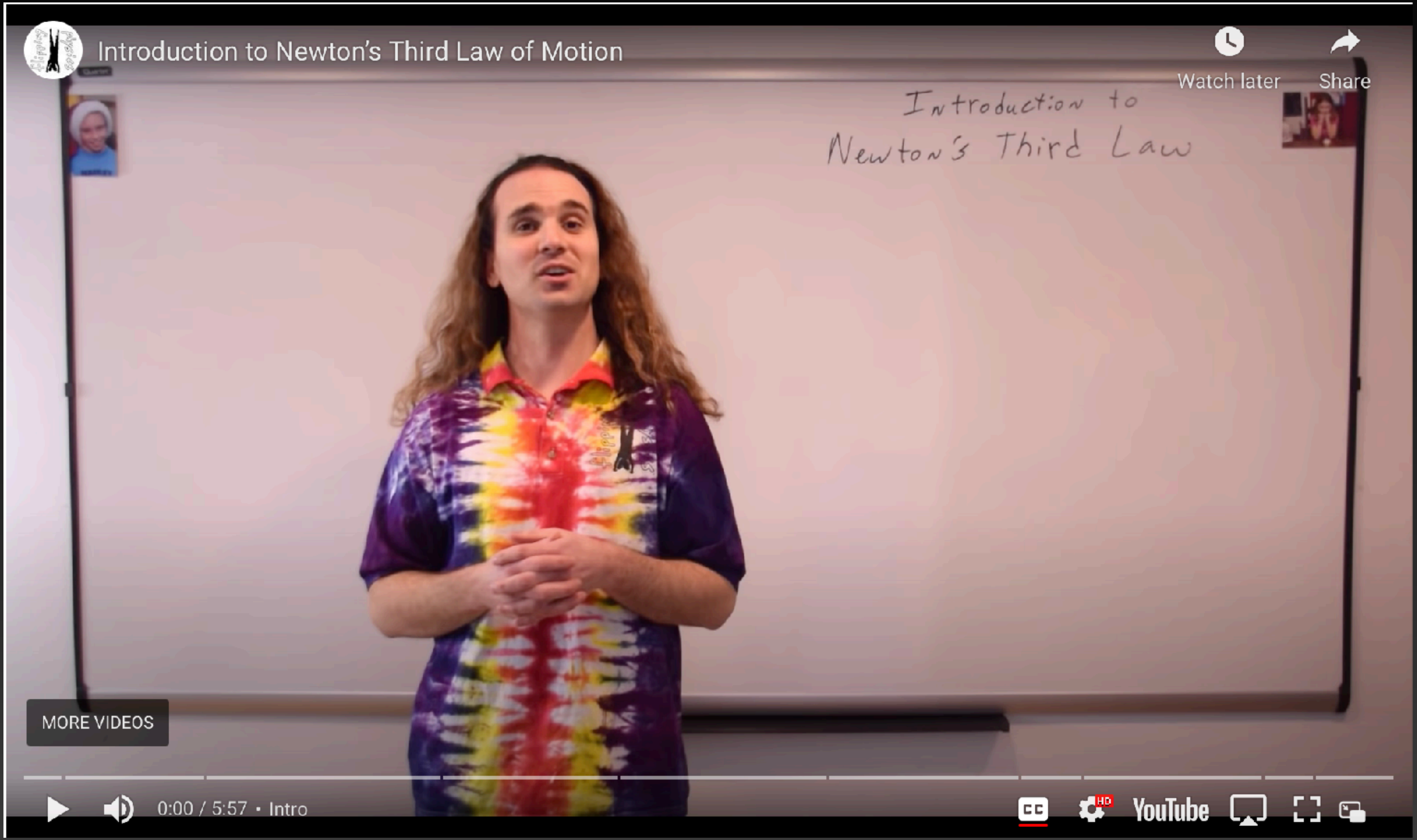
Solution

a. The forces are equal. According to Newton's first law, if the net force is zero, the velocity is constant.
b. In this case, $\vec{\mathbf{F}}_{\text{friction}}$ must be larger than $\vec{\mathbf{F}}_{\text{drag}}$. According to Newton's second law, a net force is required to cause acceleration.

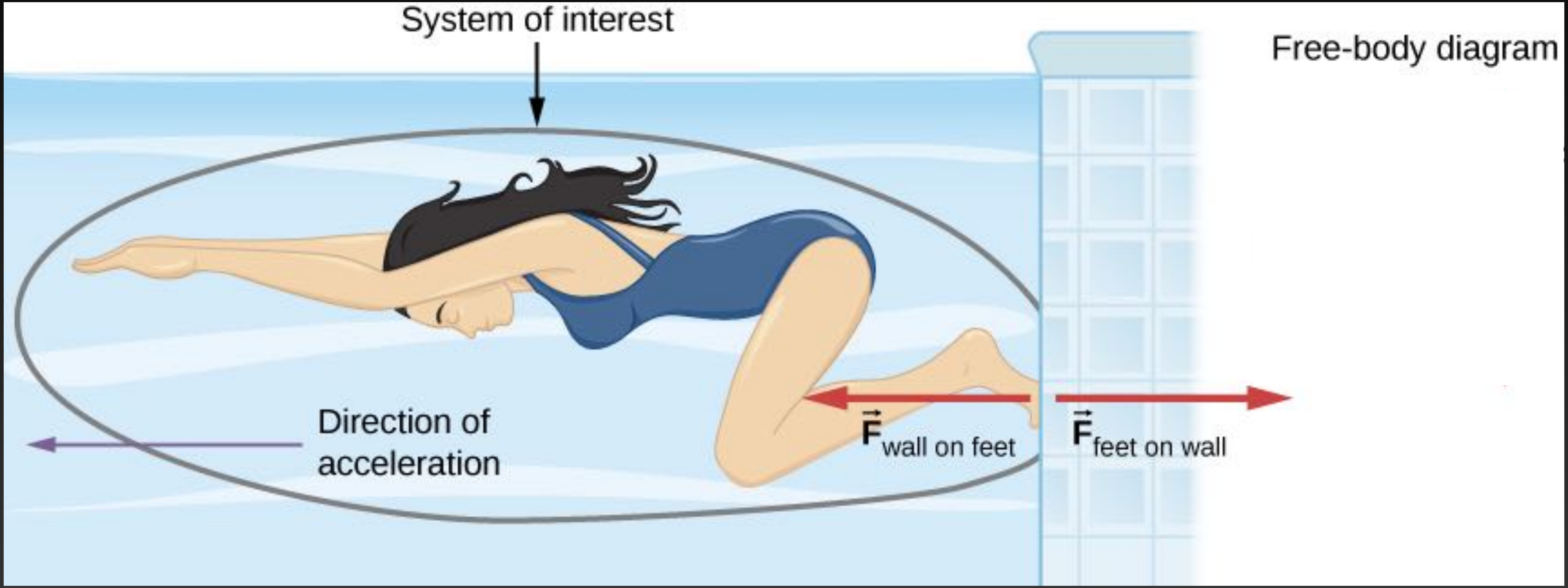
Significance

These questions may seem trivial, but they are commonly answered incorrectly. For a car or any other object to move, it must be accelerated from rest to the desired speed; this requires that the friction force be greater than the drag force. Once the car is moving at constant velocity, the net force must be zero; otherwise, the car will accelerate (gain speed). To solve problems involving Newton's laws, we must understand whether to apply Newton's first law (where $\sum \vec{\mathbf{F}} = \vec{\mathbf{0}}$) or Newton's second law (where $\sum \vec{\mathbf{F}}$ is not zero). This will be apparent as you see more examples and attempt to solve problems on your own.

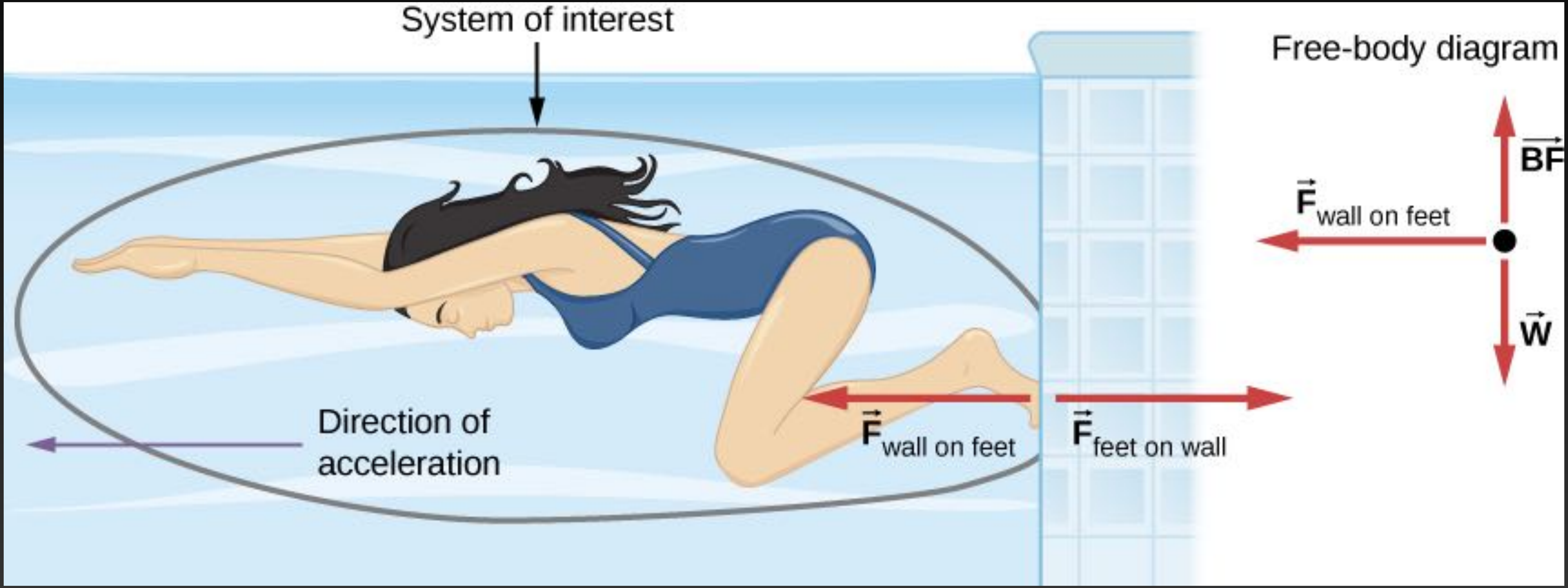
Newton's Third Law of Motion



Example: Swimmer in a Pool



Example: Swimmer in a Pool



Example: Track Runner

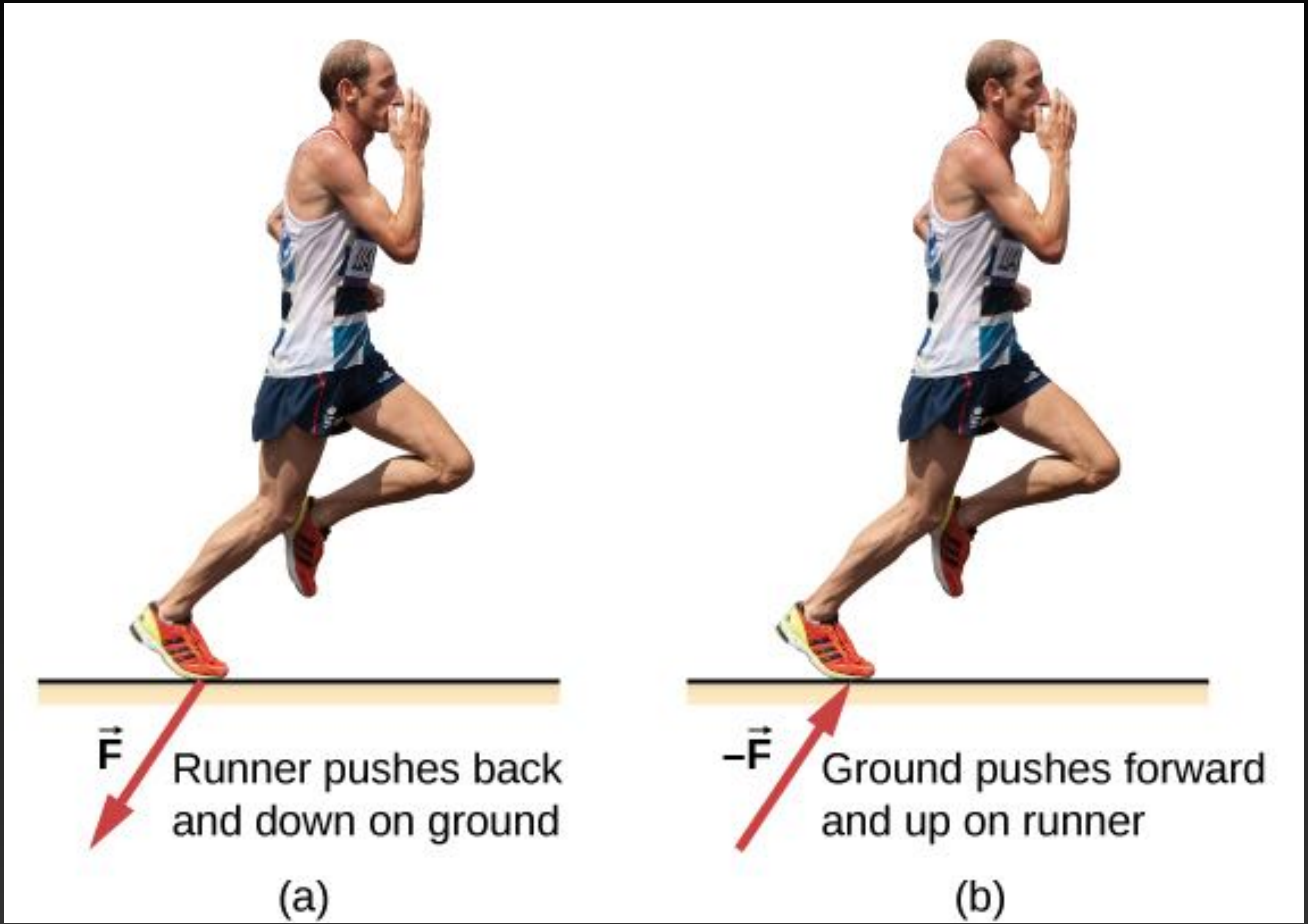
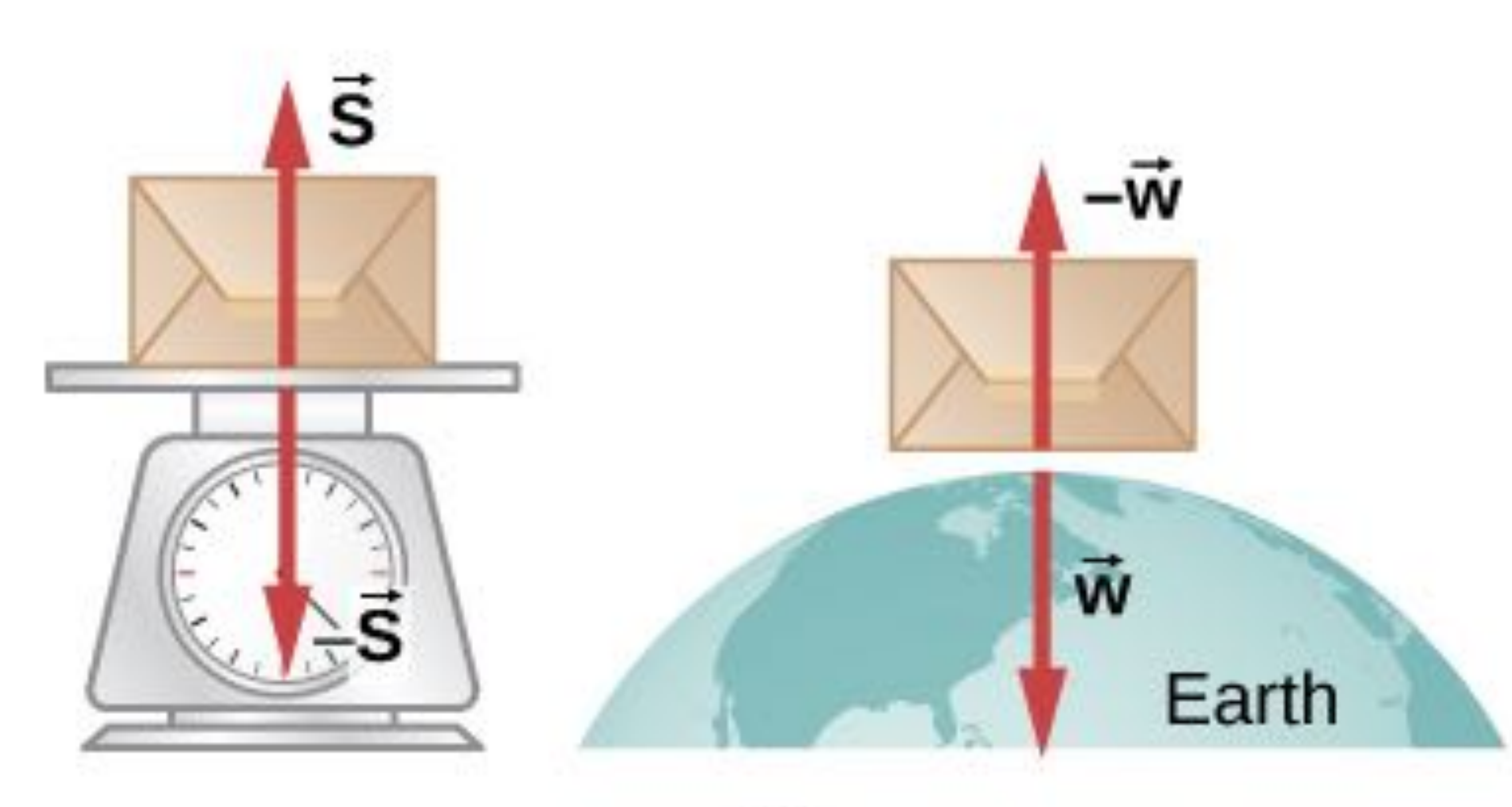


Figure 5.18
The runner experiences Newton’s third law.
(a) A force is exerted by the runner on the ground.
(b) The reaction force of the ground on the runner pushes him forward. (credit "runner": modification of work by "Greenwich Photography”/Flickr)

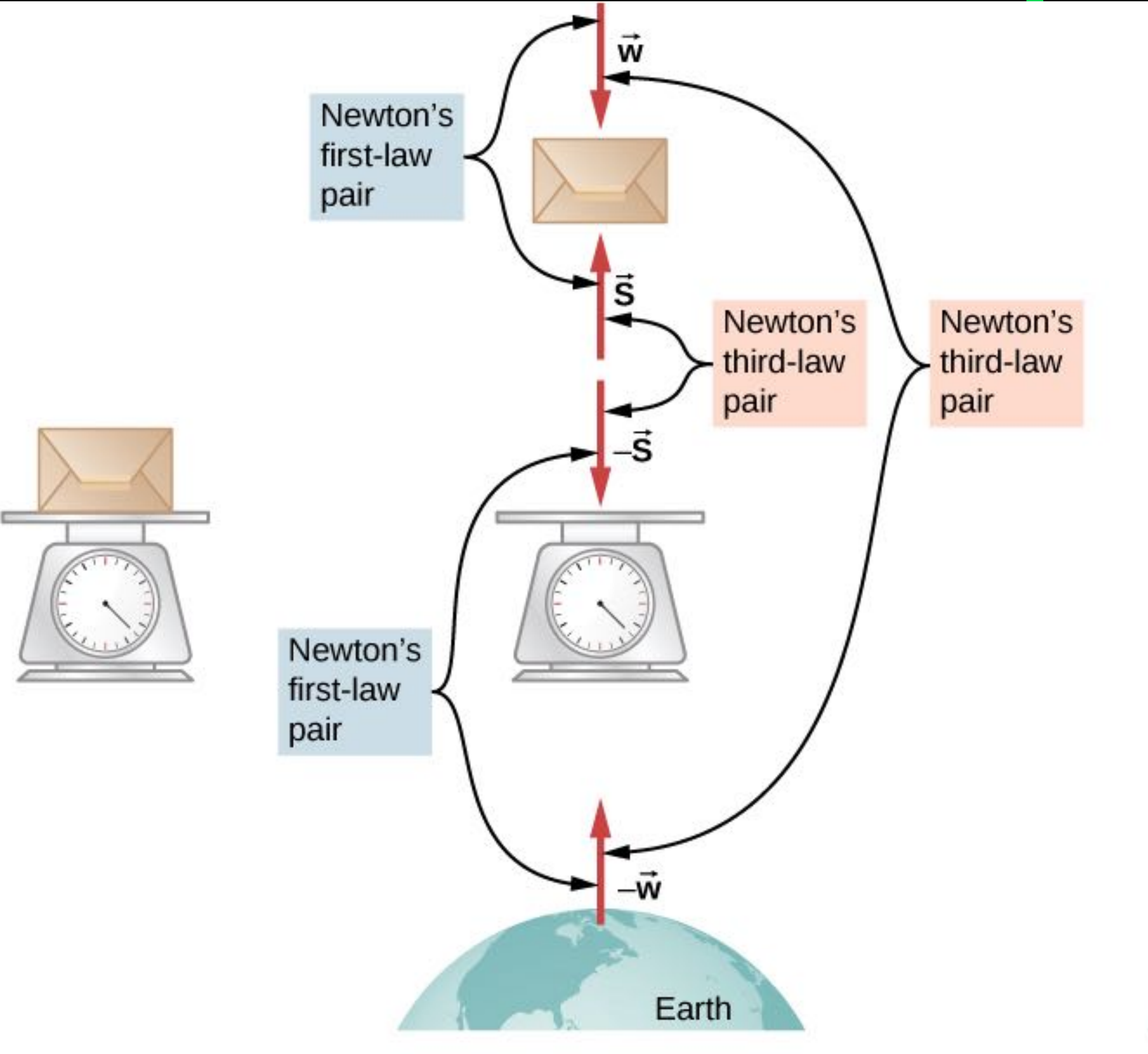
Example: Package on Scale

Example: Package on Scale

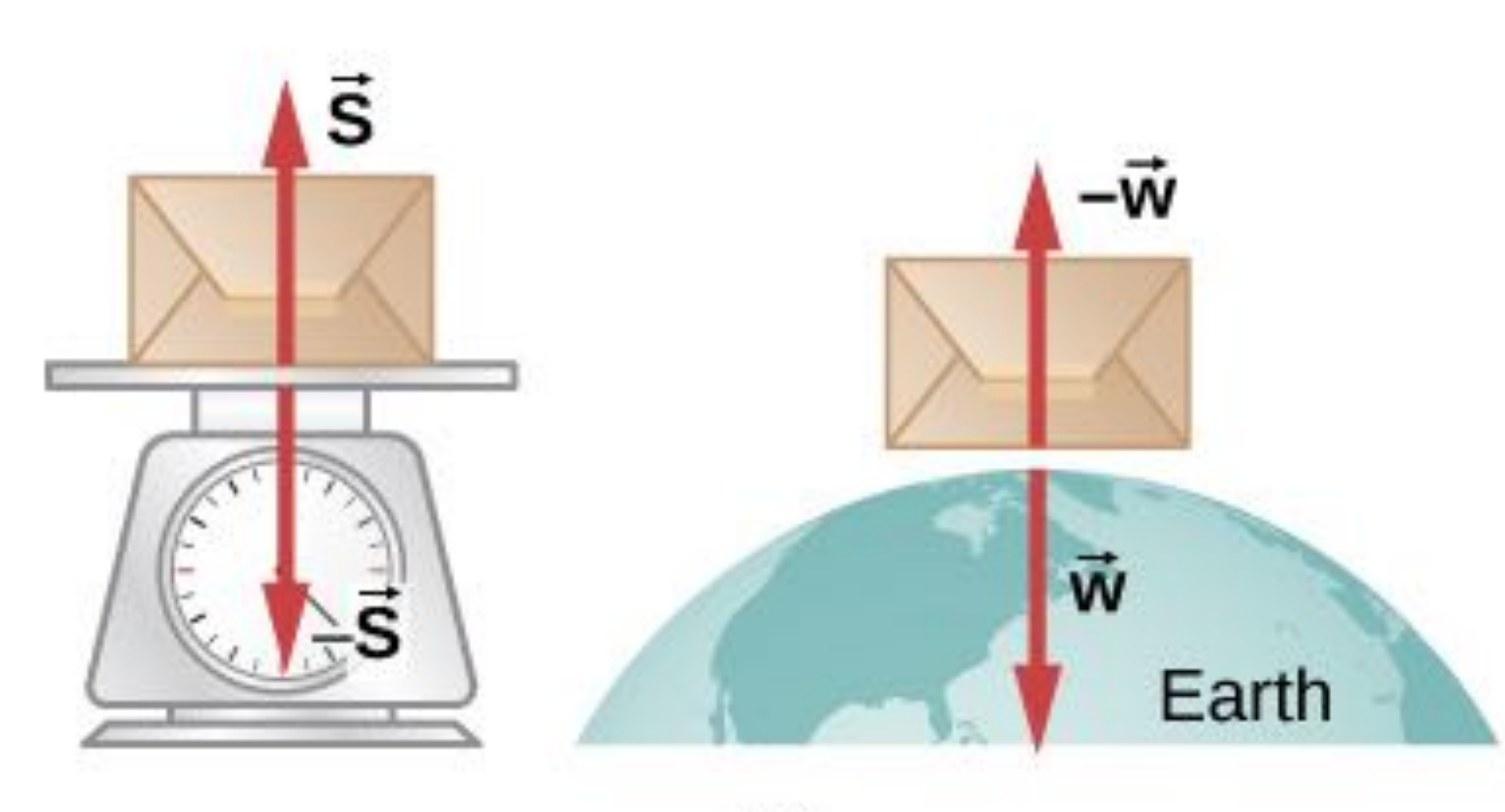


(b)

Example: Package on Scale



(a)



(b)

Common Forces

5.6 Common Forces

- When an object rests on a surface, the surface applies a force to the object that supports the weight of the object. This supporting force acts perpendicular to and away from the surface. It is called a normal force.
- When an object rests on a nonaccelerating horizontal surface, the magnitude of the normal force is equal to the weight of the object.
- When an object rests on an inclined plane that makes an angle θ with the horizontal surface, the weight of the object can be resolved into components that act perpendicular and parallel to the surface of the plane.
- The pulling force that acts along a stretched flexible connector, such as a rope or cable, is called tension. When a rope supports the weight of an object at rest, the tension in the rope is equal to the weight of the object. If the object is accelerating, tension is greater than weight, and if it is accelerating opposite to the motion, tension is less than weight.

Common Forces

5.6 Common Forces

- The force of friction is a force experienced by a moving object (or an object that has a tendency to move) parallel to the interface opposing the motion (or its tendency).
- The force developed in a spring obeys Hooke's law, according to which its magnitude is proportional to the displacement and has a sense in the opposite direction of the displacement.
- Real forces have a physical origin, whereas fictitious forces occur because the observer is in an accelerating or noninertial frame of reference.

Key Equations

Net external force	$\vec{\mathbf{F}}_{\text{net}} = \sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \cdots$
Newton's first law	$\vec{\mathbf{v}} =$ constant when $\vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{0}}\,\text{N}$
Newton's second law, vector form	$\vec{\mathbf{F}}_{\text{net}} = \sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$
Newton's second law, scalar form	$F_{\text{net}} = ma$
Newton's second law, component form	$\sum \vec{\mathbf{F}}_x = m\vec{\mathbf{a}}_x, \sum \vec{\mathbf{F}}_y = m\vec{\mathbf{a}}_y,$ and $\sum \vec{\mathbf{F}}_z = m\vec{\mathbf{a}}_z.$
Newton's second law, momentum form	$\vec{\mathbf{F}}_{\text{net}} = \frac{d\vec{\mathbf{p}}}{dt}$
Definition of weight, vector form	$\vec{\mathbf{w}} = m\vec{\mathbf{g}}$
Definition of weight, scalar form	$w = mg$

Key Equations

Newton's third law	$\vec{\mathbf{F}}_{\mathrm{AB}} = -\vec{\mathbf{F}}_{\mathrm{BA}}$
Normal force on an object resting on a horizontal surface, vector form	$\vec{\mathbf{N}} = -m\vec{\mathbf{g}}$
Normal force on an object resting on a horizontal surface, scalar form	$N = mg$
Normal force on an object resting on an inclined plane, scalar form	$N = mg\cos\theta$
Tension in a cable supporting an object of mass *m* at rest, scalar form	$T = w = mg$

Mid-course Feedback

What do you think of the course Structure so far?

- Like a great deal
- Like somewhat
- Neither like nor dislike
- Dislike somewhat
- Dislike a great deal

What do you think about the course Lectures so far?

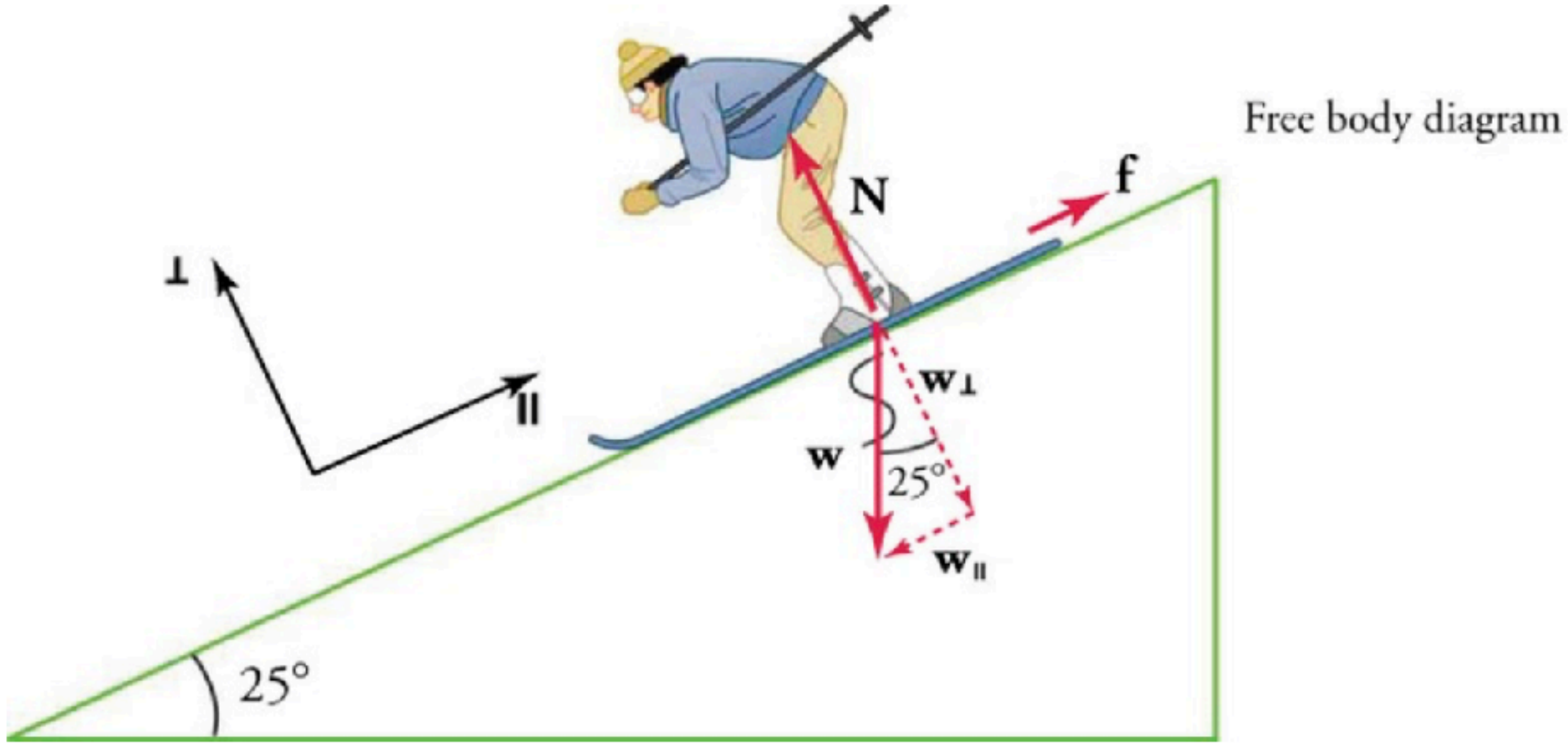
- Like a great deal
- Like somewhat
- Neither like nor dislike
- Dislike somewhat
- Dislike a great deal

How difficult are you finding the content we cover in lecture?

- Very difficult and very unfamiliar
- Appropriately difficult, and somewhat familiar
- Very easy, and very familiar

Clicker Questions

CQ.5.5



The skier's mass including equipment is 60.0 kg. The angle of inclination of the plane is

1) What is her acceleration if friction is negligible?

2) What is her acceleration if the frictional force is 45.0 N ?

a) 1) 4.14 m/s^2

2) 3.39 m/s^2

b) 1) 8.88 m/s^2

2) 3.39 m/s^2

c) 1) 4.14 m/s^2

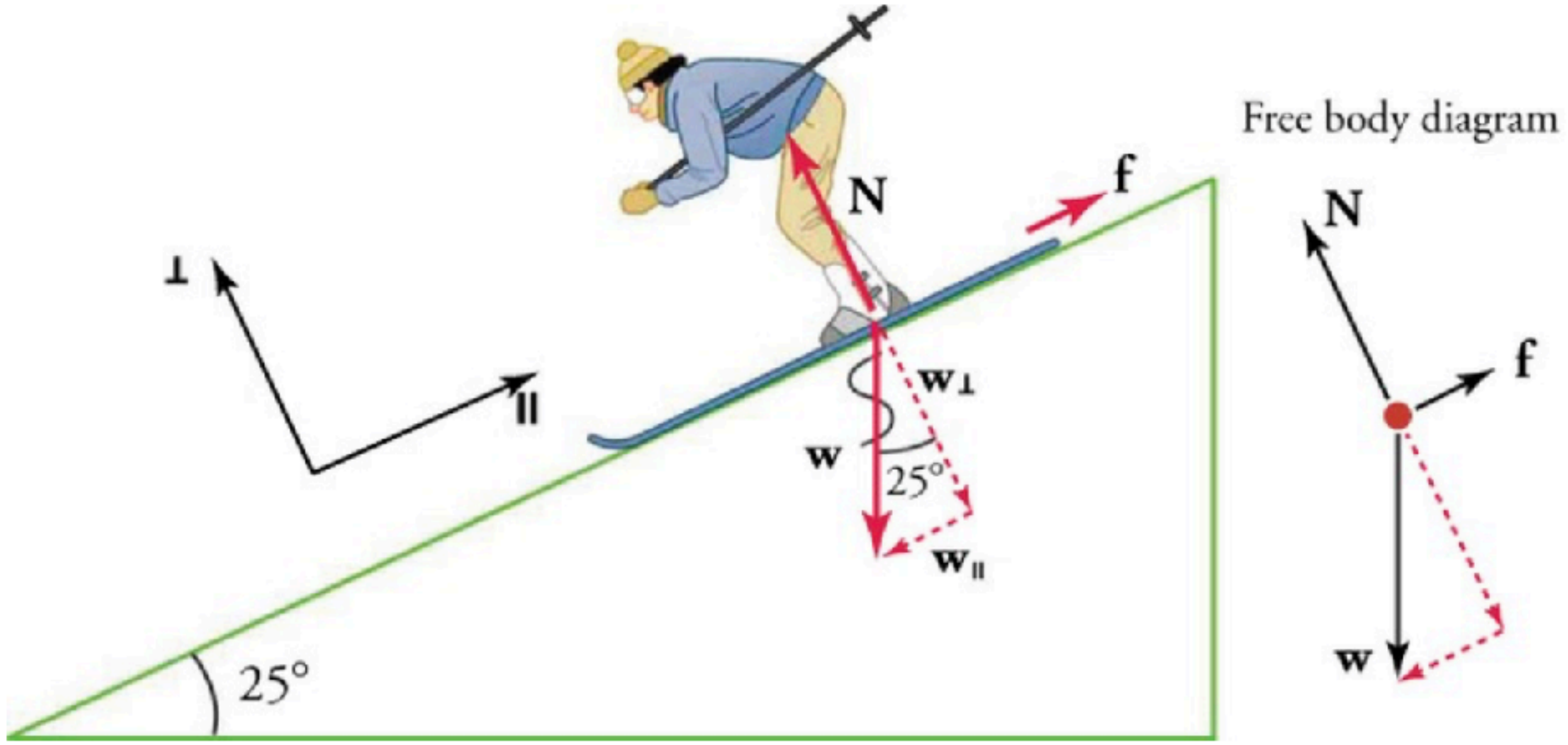
2) 8.13 m/s^2

d) 1) 8.88 m/s^2

2) 8.13 m/s^2

A B C D E

CQ.5.5



The skier's mass including equipment is $60.0\,\text{kg}$. The angle of inclination of the plane is 25°.

1) What is her acceleration if friction is negligible?

2) What is her acceleration if the frictional force is $45.0\,\text{N}$?

a) 1) $4.14\ \text{m/s}^2$

2) $3.39\ \text{m/s}^2$

The acceleration of the skier for the two cases can be obtained by using the force equation, and by resolving the component of weight of the skier appropriately, that is, using the relation $a_{||} = \frac{F_{\text{net}||}}{m}$

b) 1) $8.88\ \text{m/s}^2$

2) $3.39\ \text{m/s}^2$

Consider the parallel component of the weight correctly in the first case.

c) 1) $4.14\ \text{m/s}^2$

2) $8.13\ \text{m/s}^2$

Reconsider the parallel component of the weight, $mg\sin\theta$, in the second case.

d) 1) $8.88\ \text{m/s}^2$

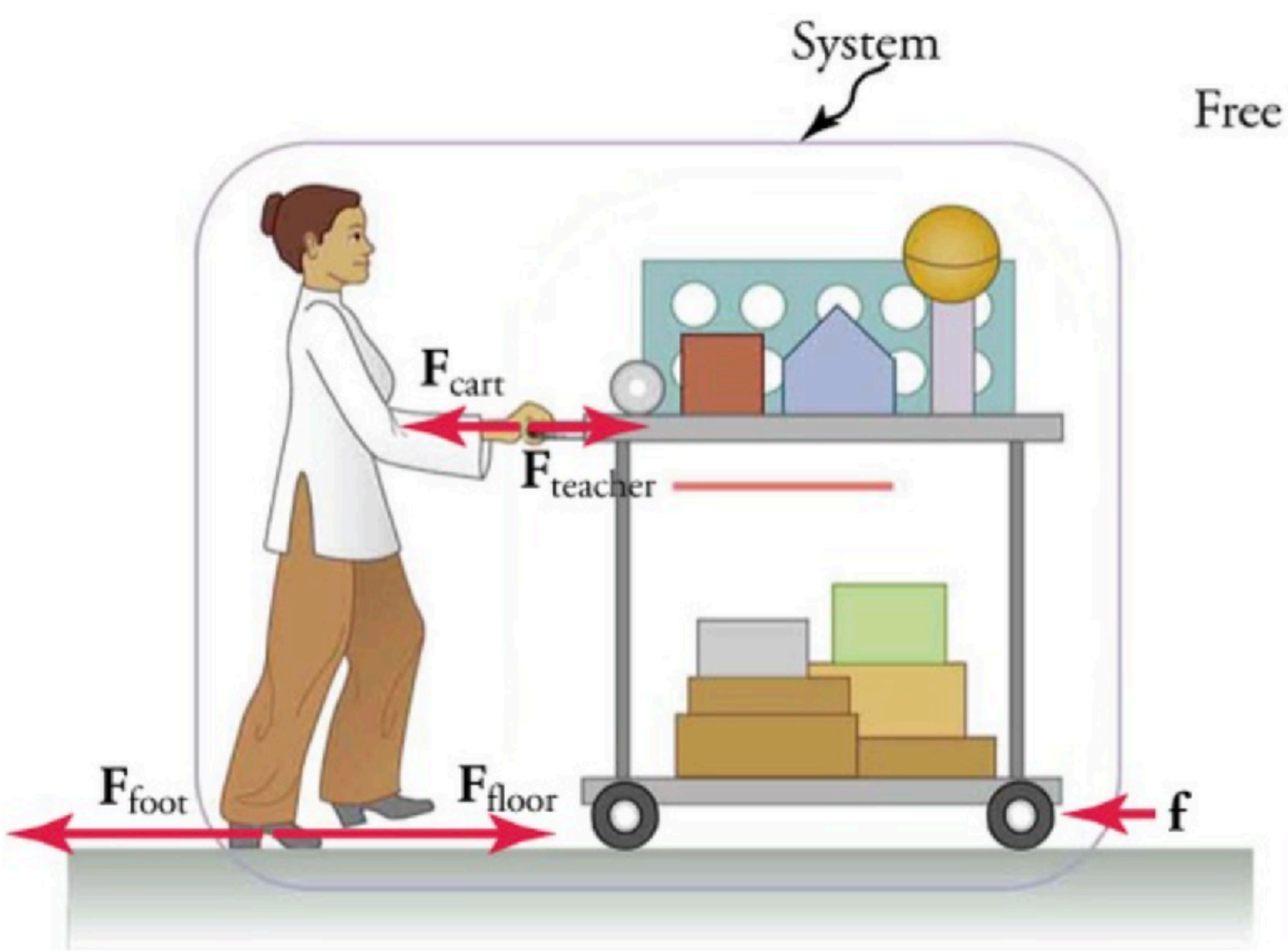
2) $8.13\ \text{m/s}^2$

The perpendicular component of the weight will not appear in the equation of motion of the skier. Also, reconsider the parallel component of the weight, $mg\sin\theta$.

Detailed solution: The acceleration of the skier for the two cases can be obtained by using the force equation, and by resolving the component of weight of the skier appropriately, that is, using the relation $a_{||} = \frac{F_{\text{net}||}}{m}$

A B C D E

CQ.5.6



A physics teacher pushes a cart of demonstration equipment to a classroom, as in Image 4.12 Her mass is $65\ \text{kg}$, the cart's mass is $12\ \text{kg}$, and the equipment's mass is $7.0\ \text{kg}$. To push the cart forward, the teacher's foot applies a force of $150\ \text{N}$ in the opposite direction (backward) on the floor. Calculate the acceleration produced by the teacher. The force of friction, which opposes the motion, is $24.0\ \text{N}$.

a) $0.29\ \text{m/s}^2$

b) $1.5\ \text{m/s}^2$

c) $1.8\ \text{m/s}^2$

d) $2.1\ \text{m/s}^2$

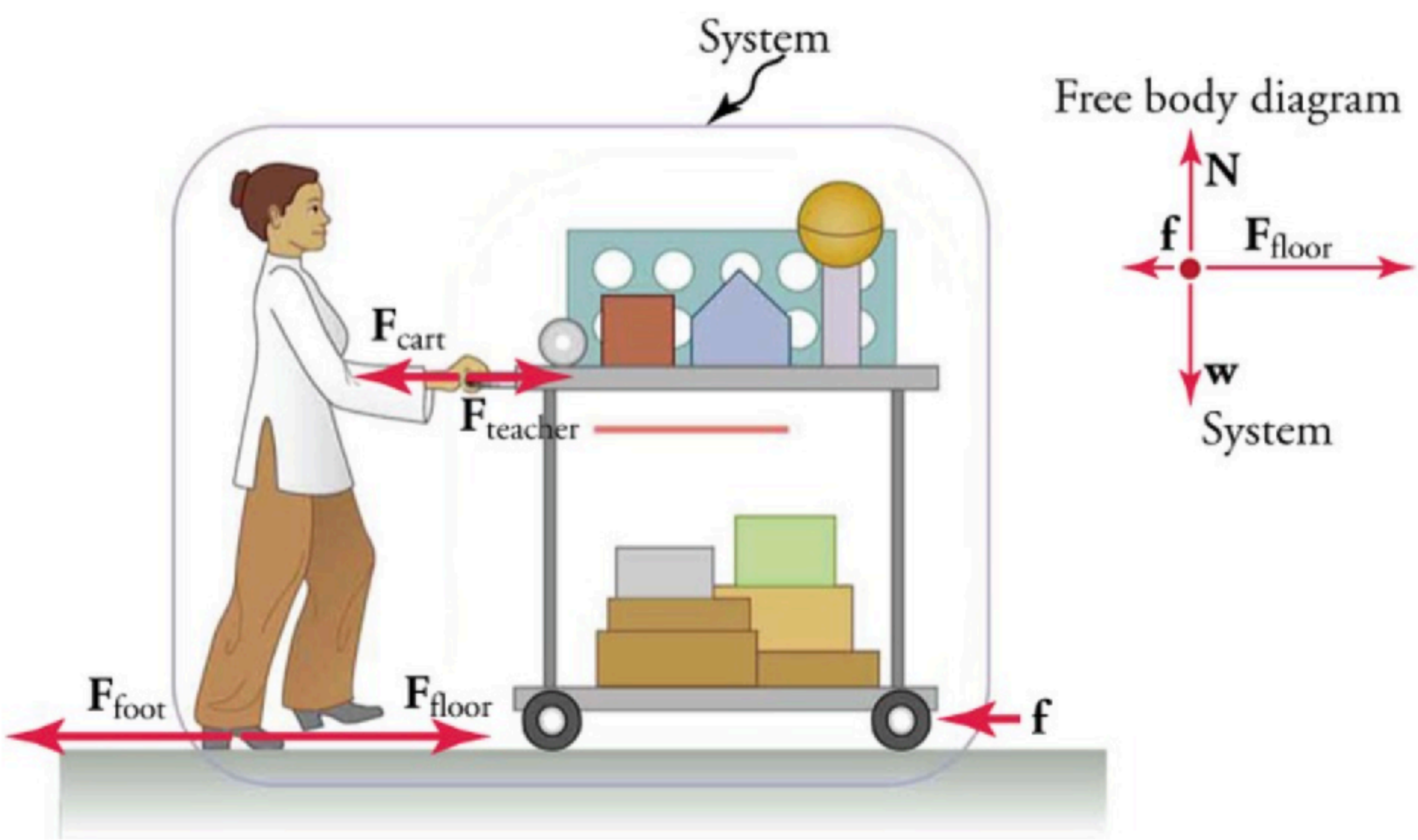
A

B

C

D

CQ.5.6



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a) $0.29\ m/s^2$

Acceleration can determined after dividing net force by total mass of the system.

✓ b) $1.5\ m/s^2$

The acceleration of the system is defined as the net force acting on the system divided by the total mass of the system.

c) $1.8\ m/s^2$

The net external force acting on the system does not include acomponent of the frictional force.

d) $2.1\ m/s^2$

The frictional force and the external force due to the floor do not act in opposite directions.

A

B

C

D

CQ.5.7

A helicopter pushes air down, which in turn pushes the helicopter up. Which force affects the helicopter's motion? Why?

a) Air pushing upward affects the helicopter's motion because it is an internal force that acts on the helicopter.

b) Air pushing upward affects the helicopter's motion because it is an external force that acts on the helicopter.

c) The downward force applied by the blades of the helicopter affects its motion because it is an internal force that acts on the helicopter.

d) The downward force applied by the blades of the helicopter affects its motion because it is an external force that acts on the helicopter.

A B C D E

CQ.5.7

A helicopter pushes air down, which in turn pushes the helicopter up. Which force affects the helicopter's motion? Why?

a) Air pushing upward affects the helicopter's motion because it is an internal force that acts on the helicopter.

✓ b) Air pushing upward affects the helicopter's motion because it is an external force that acts on the helicopter.

c) The downward force applied by the blades of the helicopter affects its motion because it is an internal force that acts on the helicopter.

d) The downward force applied by the blades of the helicopter affects its motion because it is an external force that acts on the helicopter.

Detailed solution: The air pushing upward affects the helicopter's motion. The downward force applied by the helicopter on the air is internal to the system (helicopter) and thus does not affect its motion.

A B C D E

CQ.5.8

A fish pushes water backward with its fins. How does this propel the fish forward?

a) The water exerts an internal force on the fish in the opposite direction, pushing the fish forward.

b) The water exerts an external force on the fish in the opposite direction, pushing the fish forward.

c) The water exerts an internal force on the fish in the same direction, pushing the fish forward.

d) The water exerts an external force on the fish in the same direction, pushing the fish forward.

A B C D E

CQ.5.8

A fish pushes water backward with its fins. How does this propel the fish forward?

a) The water exerts an internal force on the fish in the opposite direction, pushing the fish forward.

✓ b) The water exerts an external force on the fish in the opposite direction, pushing the fish forward.

c) The water exerts an internal force on the fish in the same direction, pushing the fish forward.

d) The water exerts an external force on the fish in the same direction, pushing the fish forward.

Detailed solution: The water exerts a force on the fish in the opposite direction that pushes the fish forward.

A B C D E

Activity:
Worked Problem

EXAMPLE 5.13

What Is the Tension in a Tightrope?

Calculate the tension in the wire supporting the 70.0-kg tightrope walker shown in Figure 5.26.

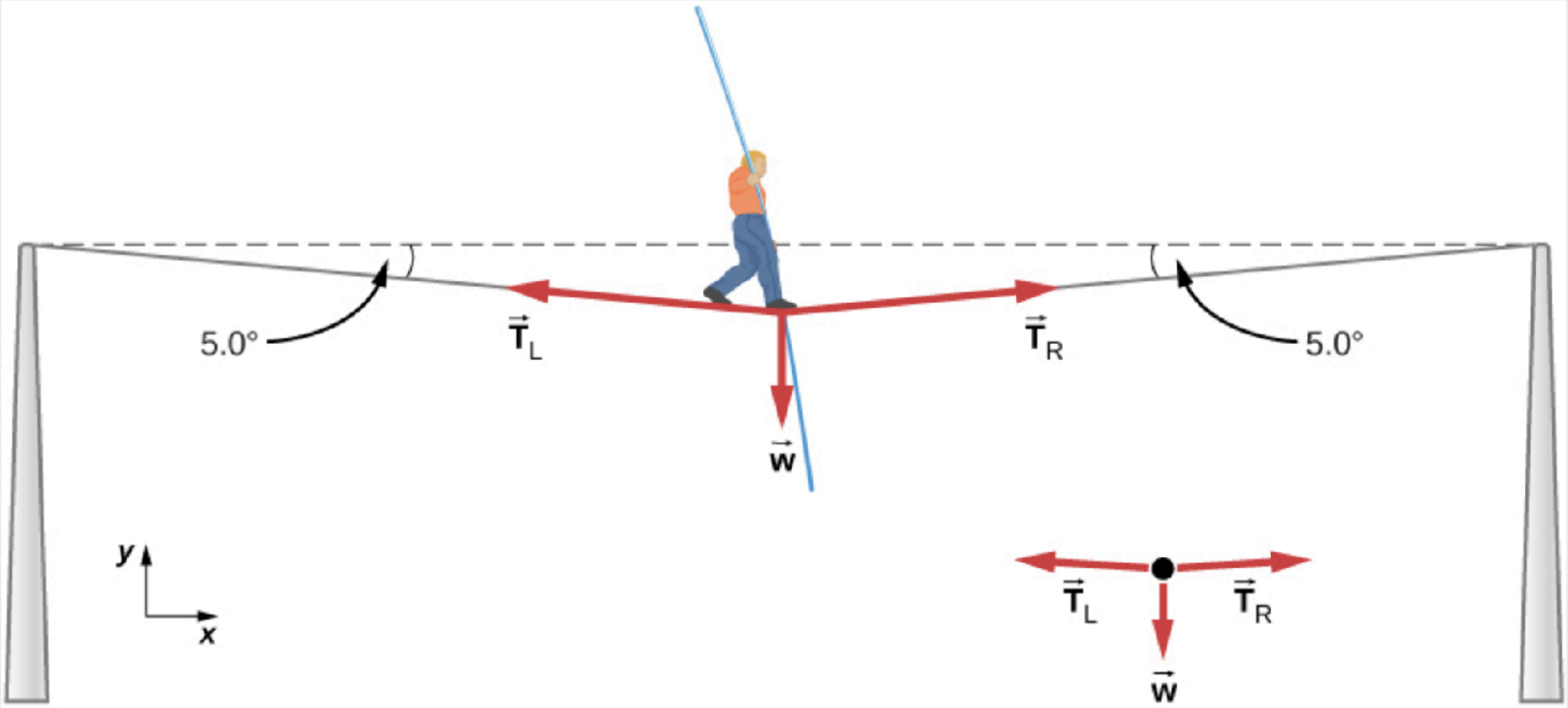


Figure 5.26 The weight of a tightrope walker causes a wire to sag by $5.0°$. The system of interest is the point in the wire at which the tightrope walker is standing.

WP 5.3

WP 5.3

EXAMPLE 5.13

What Is the Tension in a Tightrope?

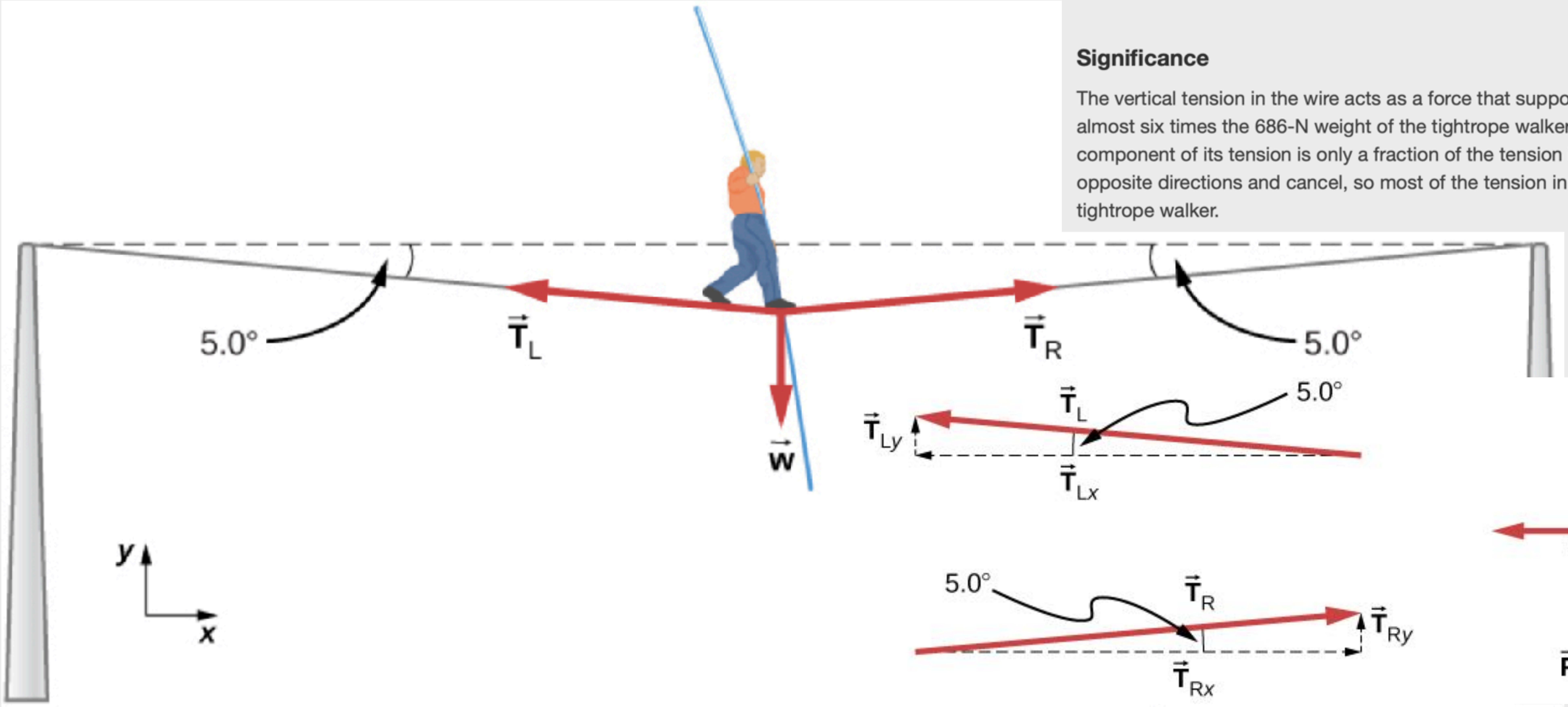
Calculate the tension in the wire supporting the 70.0-kg tightrope walker shown in Figure 5.26.

and the tension is

$$T = 3930\ \mathrm{N}.$$

Significance

The vertical tension in the wire acts as a force that supports the weight of the tightrope walker. The tension is almost six times the 686-N weight of the tightrope walker. Since the wire is nearly horizontal, the vertical component of its tension is only a fraction of the tension in the wire. The large horizontal components are in opposite directions and cancel, so most of the tension in the wire is not used to support the weight of the tightrope walker.



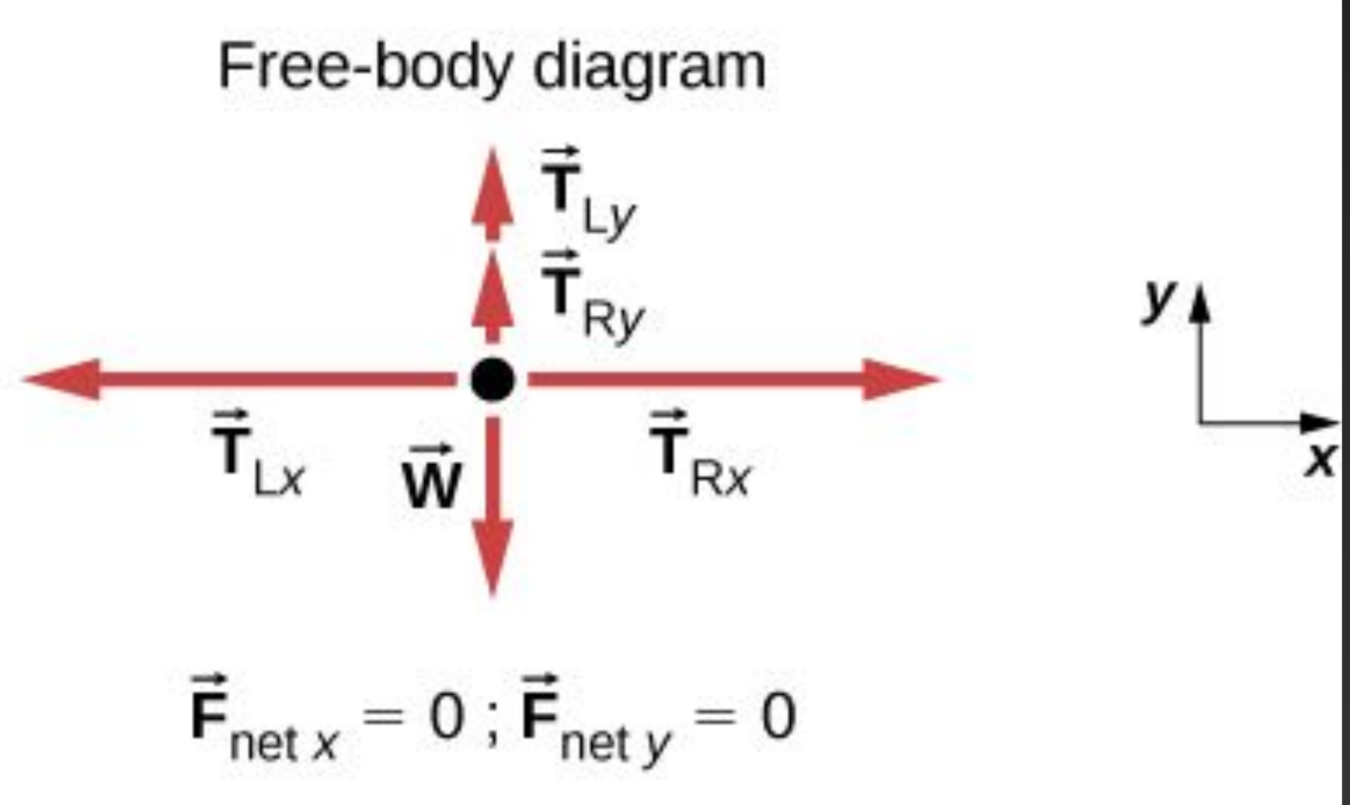
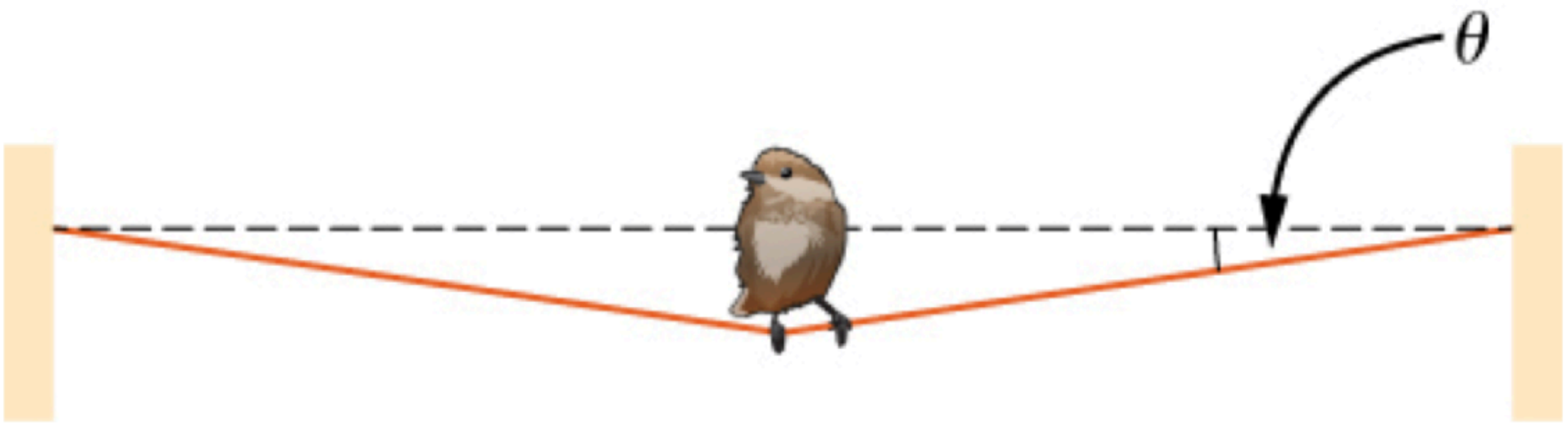


Figure 5.26 The weight of a tightrope walker causes a wire to sag by $5.0°$. The system of interest is the point in the wire at which the tightrope walker is standing.

WP 5.4

63 . A bird has a mass of 26 g and perches in the middle of a stretched telephone line. (a) Show that the tension in the line can be calculated using the equation $T = \frac{mg}{2 \sin \theta}$. Determine the tension when (b) $\theta = 5°$ and (c) $\theta = 0.5°$. Assume that each half of the line is straight.



WP 5.4

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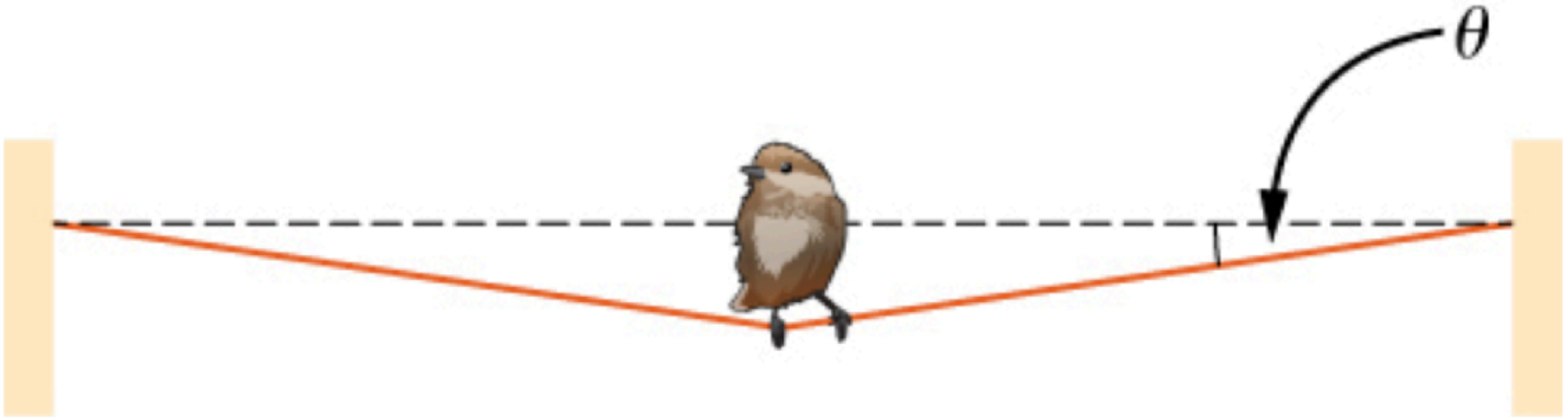

b. 1.5 N; c. 15 N

See you next class!

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