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Physics 111 - Class 5B
Forces II

Do not draw in/on this box!

October 5, 2021

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Class Outline

- Logistics / Announcements
- Introduction to Chapter 5
- Clicker Questions
- Activity: Worked Problem

Logistics/Announcements

- Lab this week: Lab 3
- HW5 due this week on Thursday at 6 PM
  - New: Finish HW5 with 100% by Wednesday 6PM and get a 10% bonus!
- 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 Window: Friday 6 PM - Sunday 6 PM

Physics 111

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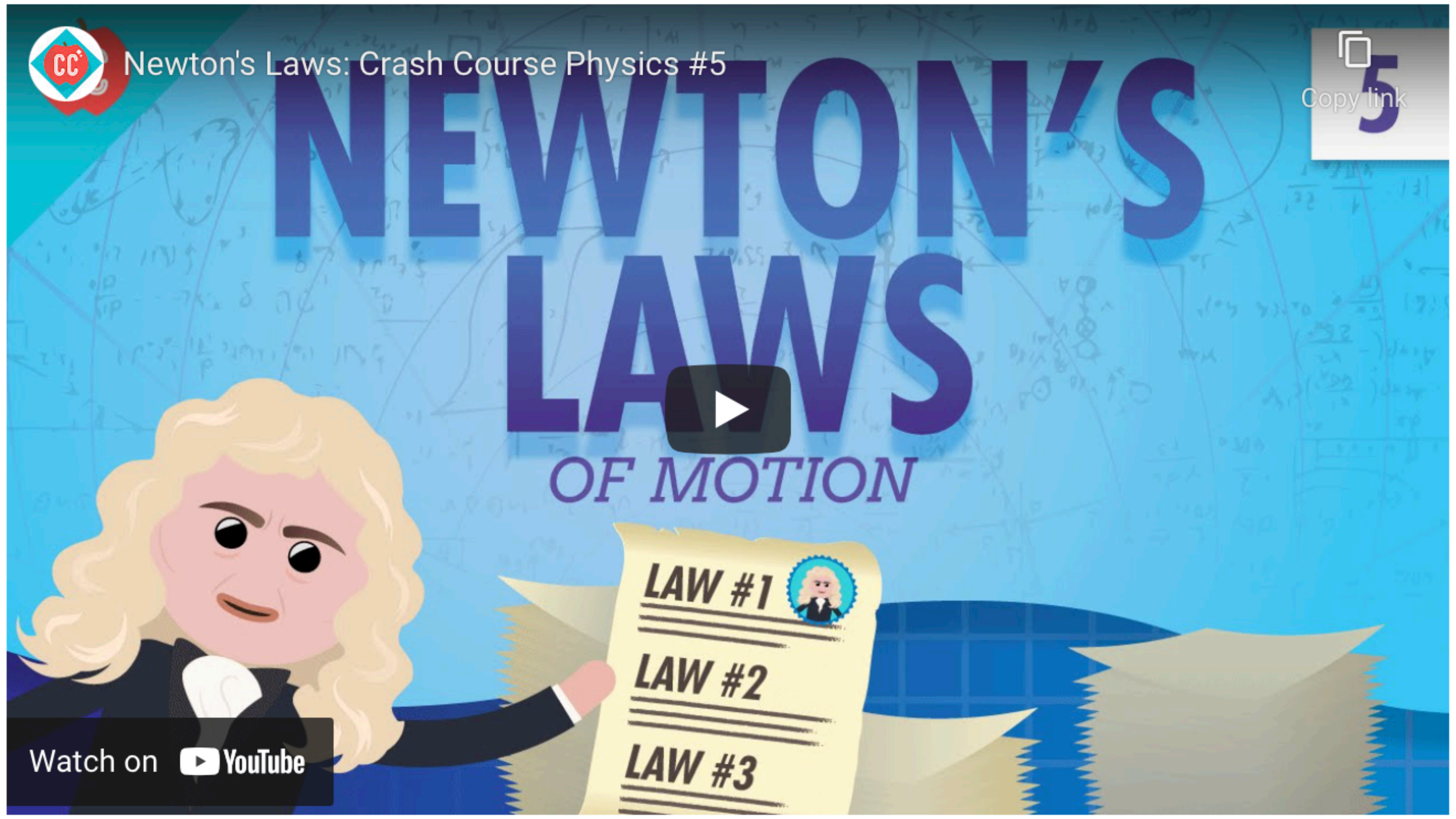
Content Summary from Crash Course Physics

Newton's Laws



Required Videos

1. Introduction to Inertia and Inertial Mass

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

Introduction

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

Introduction

Table of contents

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My highlights

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Chapter Outline

Wednesday’s Class

5.2 Newton’s First Law
5.3 Newton’s Second Law

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.

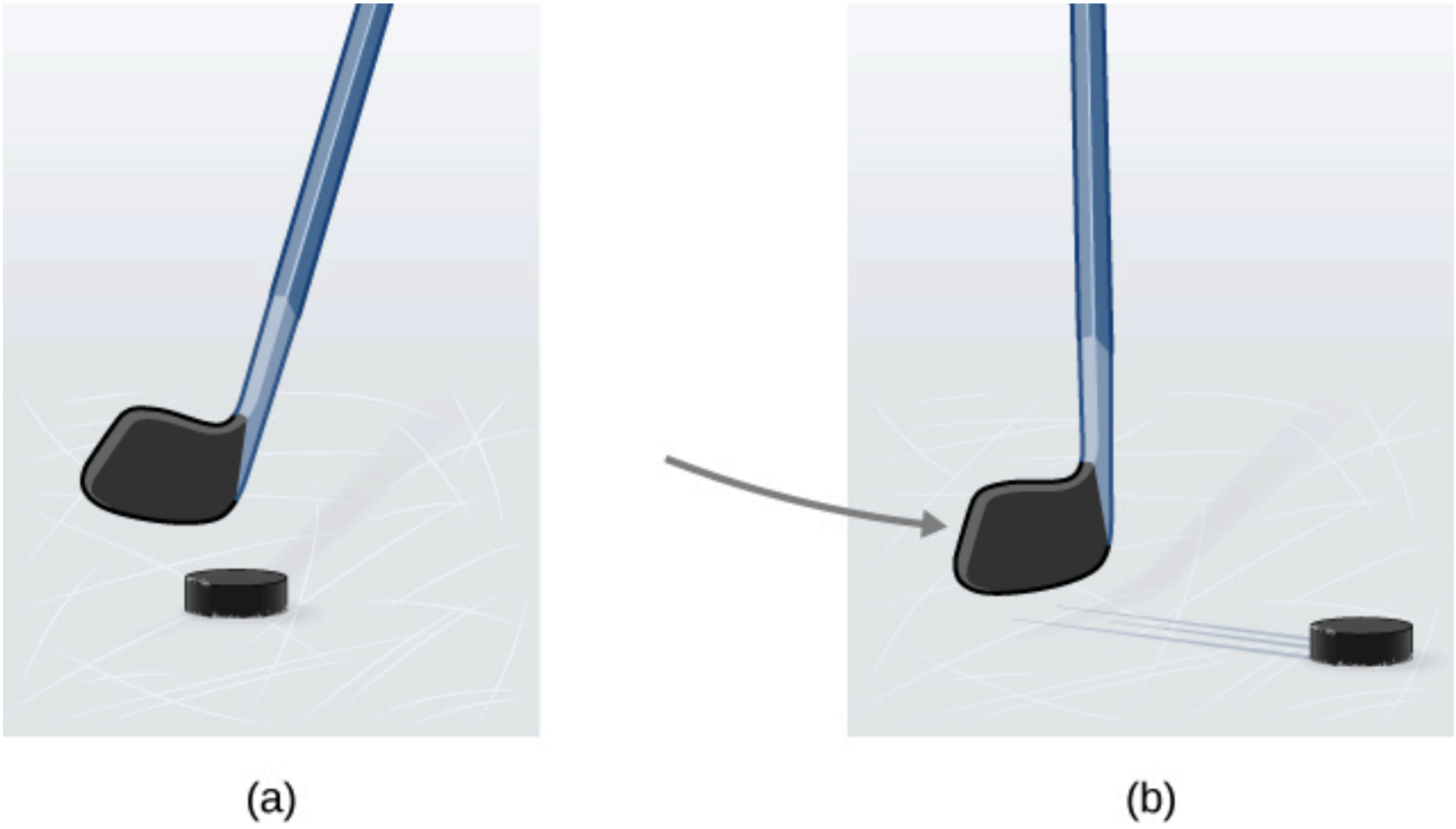

Figure 5.7 (a) A hockey puck is shown at rest; it remains at rest until an outside force such as a hockey stick changes its state of rest; (b) a hockey puck is shown in motion; it continues in motion in a straight line until an outside force causes it to change its state of motion. Although it is slick,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

Applying Newton's First Law

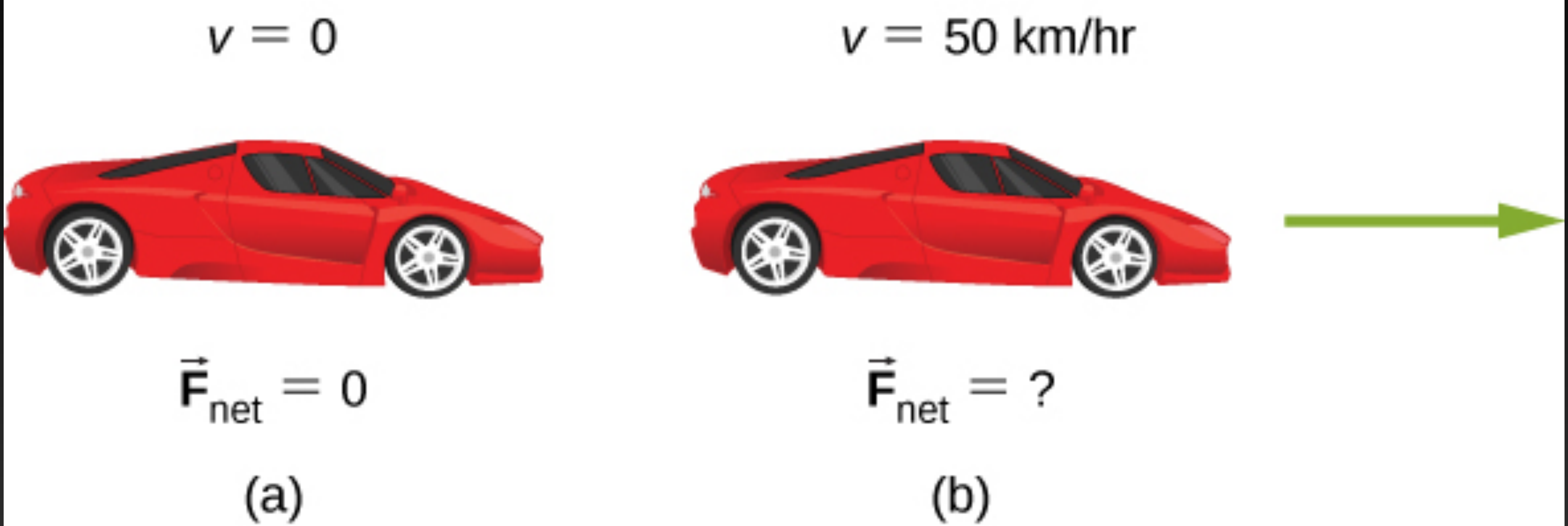

Figure 5.9
(a) A car is parked and has a velocity of 0 km/hr. What is the net force on this car?
(b) A car is moving at a constant velocity of 50 km/hr. What is the net force on the car?

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

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

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:

$$F_{\text{net}} = ma. \qquad \boxed{5.4}$$

Applying Newton's Second Law

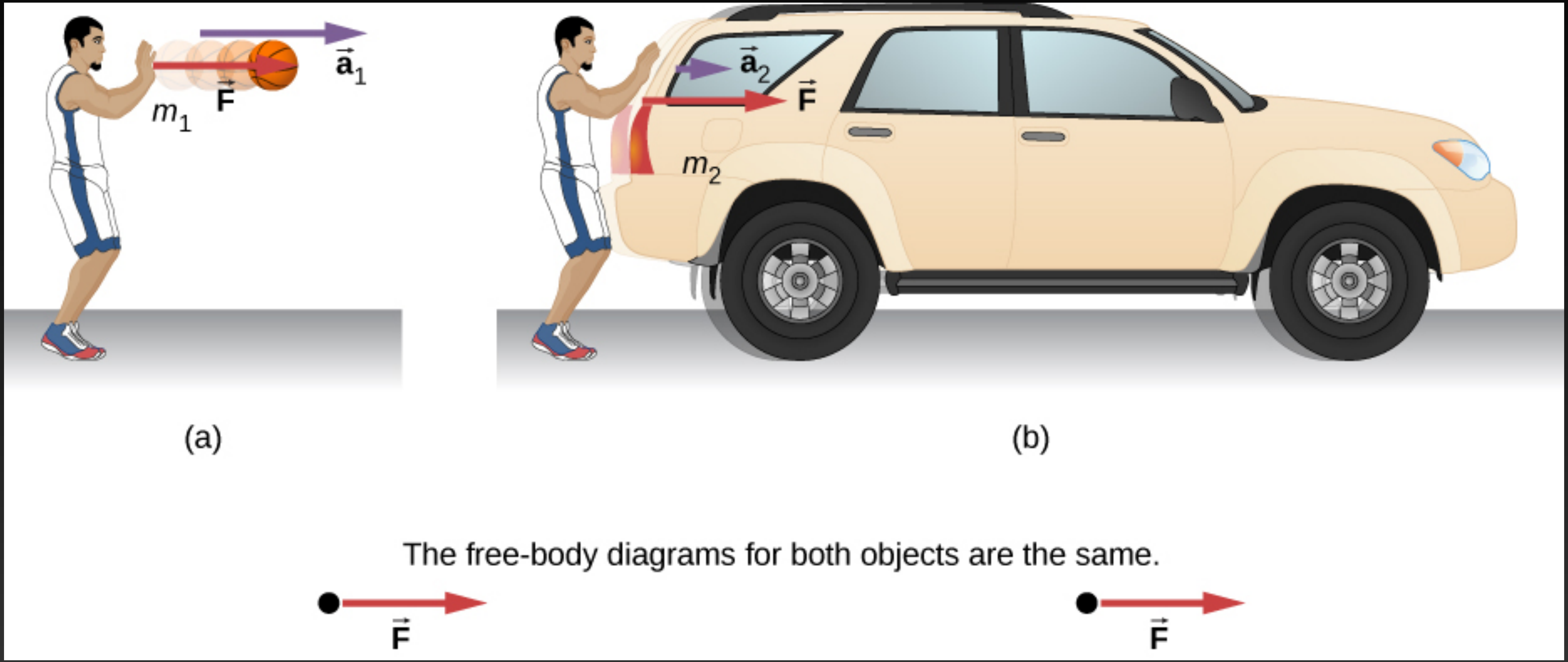

Figure 5.11

(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.

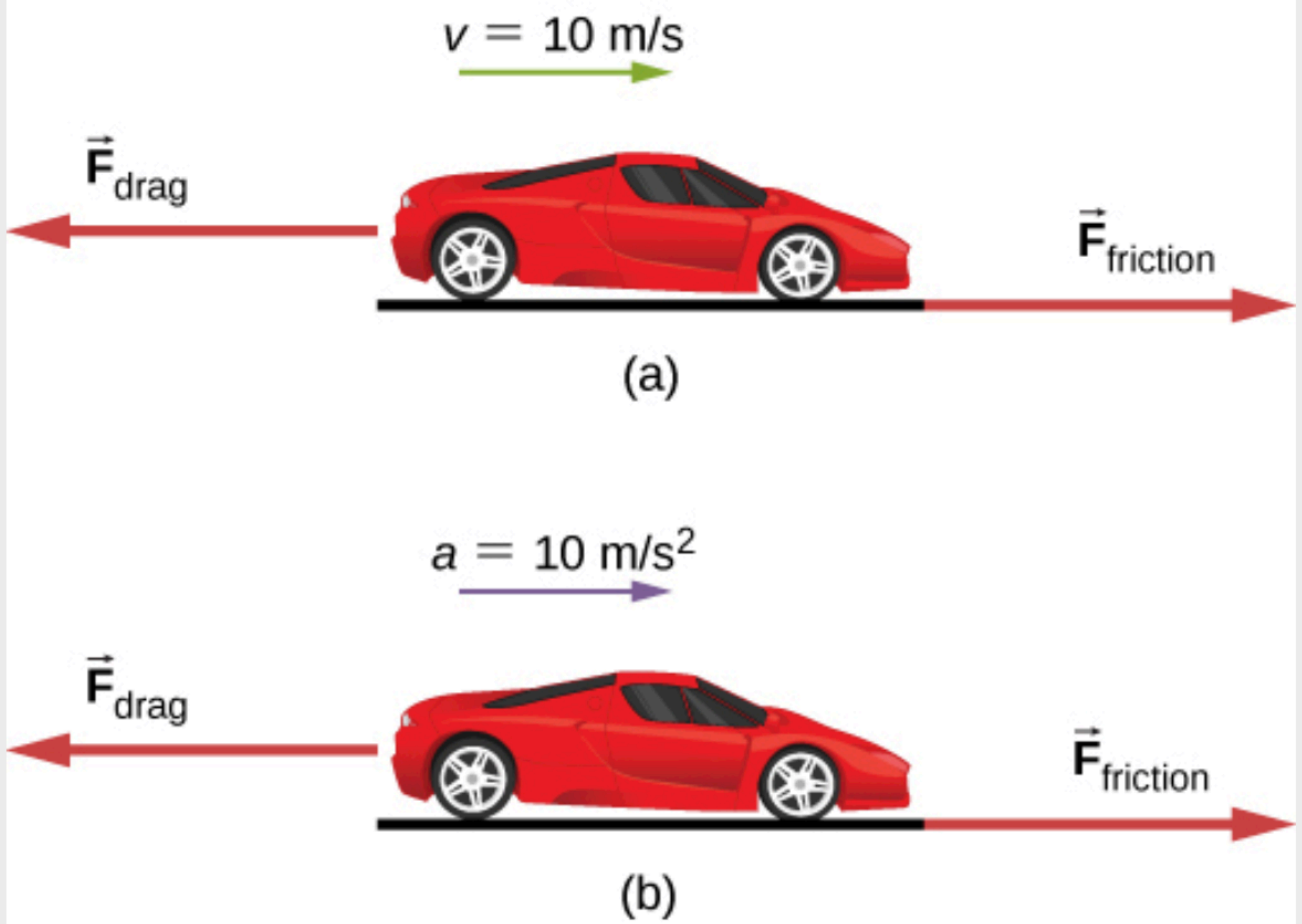

Figure 5.13 A car is shown (a) moving at constant speed and (b) accelerating. How do the forces acting on the car compare in each case? (a) What does the knowledge that the car is moving at constant velocity tell us about the net horizontal force on the car compared to the friction force? (b) What does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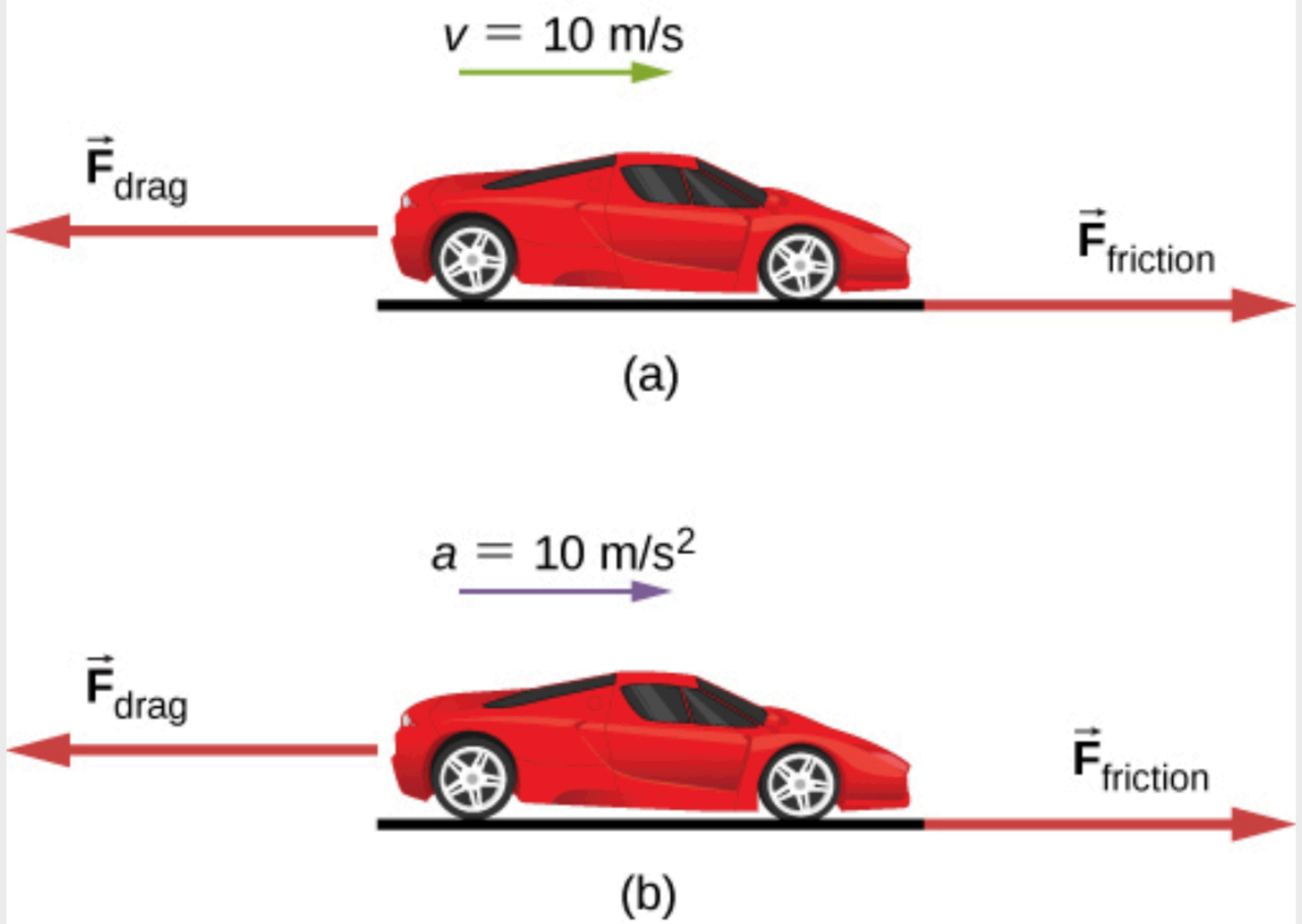

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Strategy

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.

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	$w = mg$

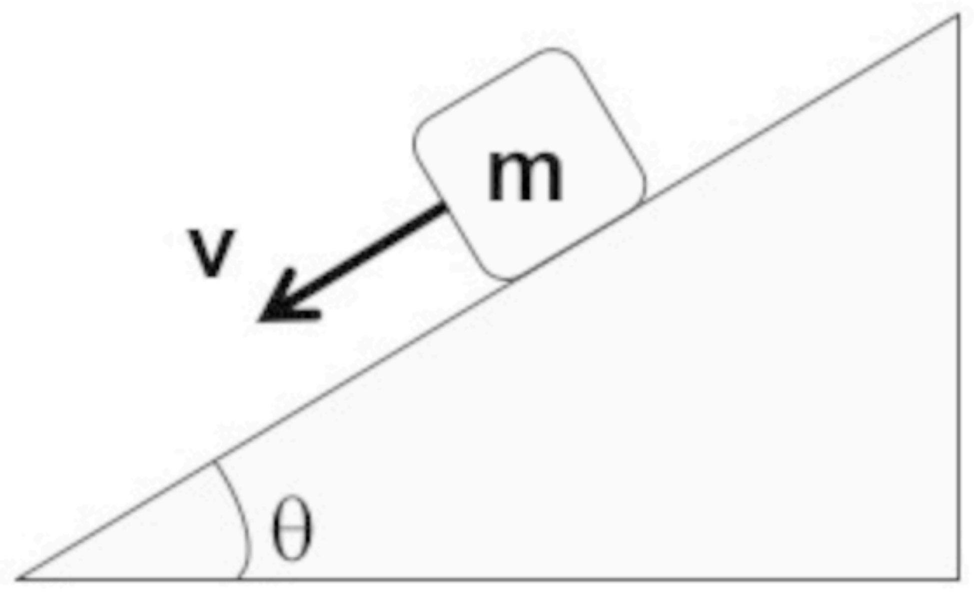
Key Equations

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	$T = w = mg$

Clicker Questions

CQ.4.3

An object slides down an inclined plane as in this figure. A frictional force acts on the block. Which of these statements is true?



I.	The frictional force is up the inclined plane.
II.	The frictional force depends on the mass of the object.
III.	If θ increases, the frictional force will always decrease.
IV.	The frictional force is dependent on the speed of the object.

a) I & II

b) I, II, and III

c) I only

d) II & IV

e) I & III

A B C D E

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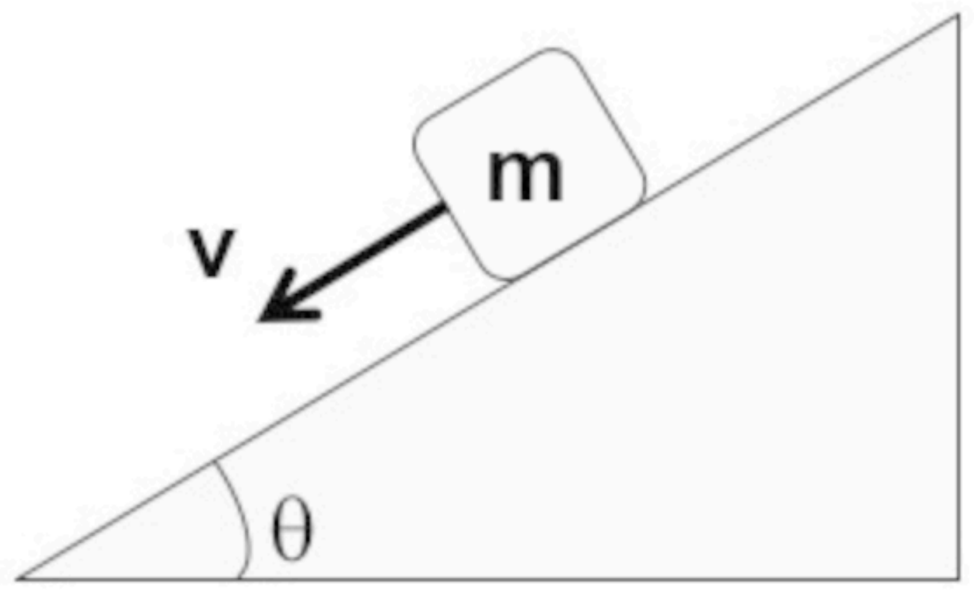

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a) I & II

✓ b) I, II, and III

c) I only

d) II & IV

e) I & III

A B C D E

CQ.4.4

A $50\,\mathrm{kg}$ box is being slid down a wooden inclined plane with an incline of 55°. If the frictional force it experiences is $80\,\mathrm{N}$, what component of the acceleration parallel to the incline will it achieve? Consider down the plane to be the positive direction.

a) $-6.43\ \mathrm{m/s^2}$

b) $-4.02\ \mathrm{m/s^2}$

c) $4.02\ \mathrm{m/s^2}$

d) $6.43\ \mathrm{m/s^2}$

A B C D E

CQ.4.4

A $50\ \mathrm{kg}$ box is being slid down a wooden inclined plane with an incline of 55°. If the frictional force it experiences is $80\ \mathrm{N}$, what component of the acceleration parallel to the incline will it achieve? Consider down the plane to be the positive direction.

a) $-6.43\ \mathrm{m/s^2}$

b) $-4.02\ \mathrm{m/s^2}$

c) $4.02\ \mathrm{m/s^2}$

✓ d) $6.43\ \mathrm{m/s^2}$

Detailed solution:

$$a_{||} = \frac{F_{\text{net}\,||}}{m} = \frac{w_{||} - f}{m} = \frac{mg\sin\theta - f}{m} = \frac{(50)\,(9.8)\sin(55) - 80}{50} = 6.43\ \mathrm{m/}$$

A

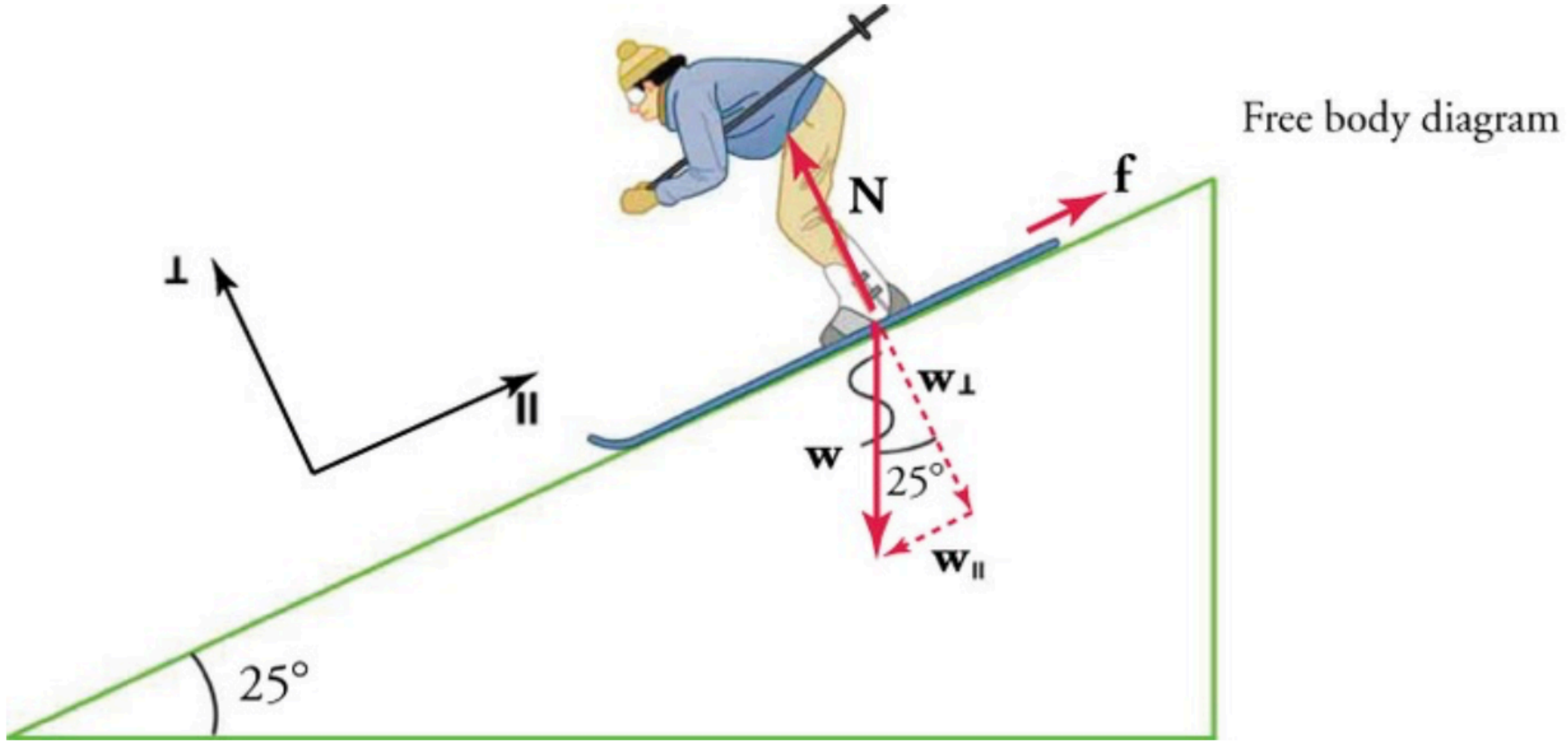
B

C

D

E

CQ.4.5



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

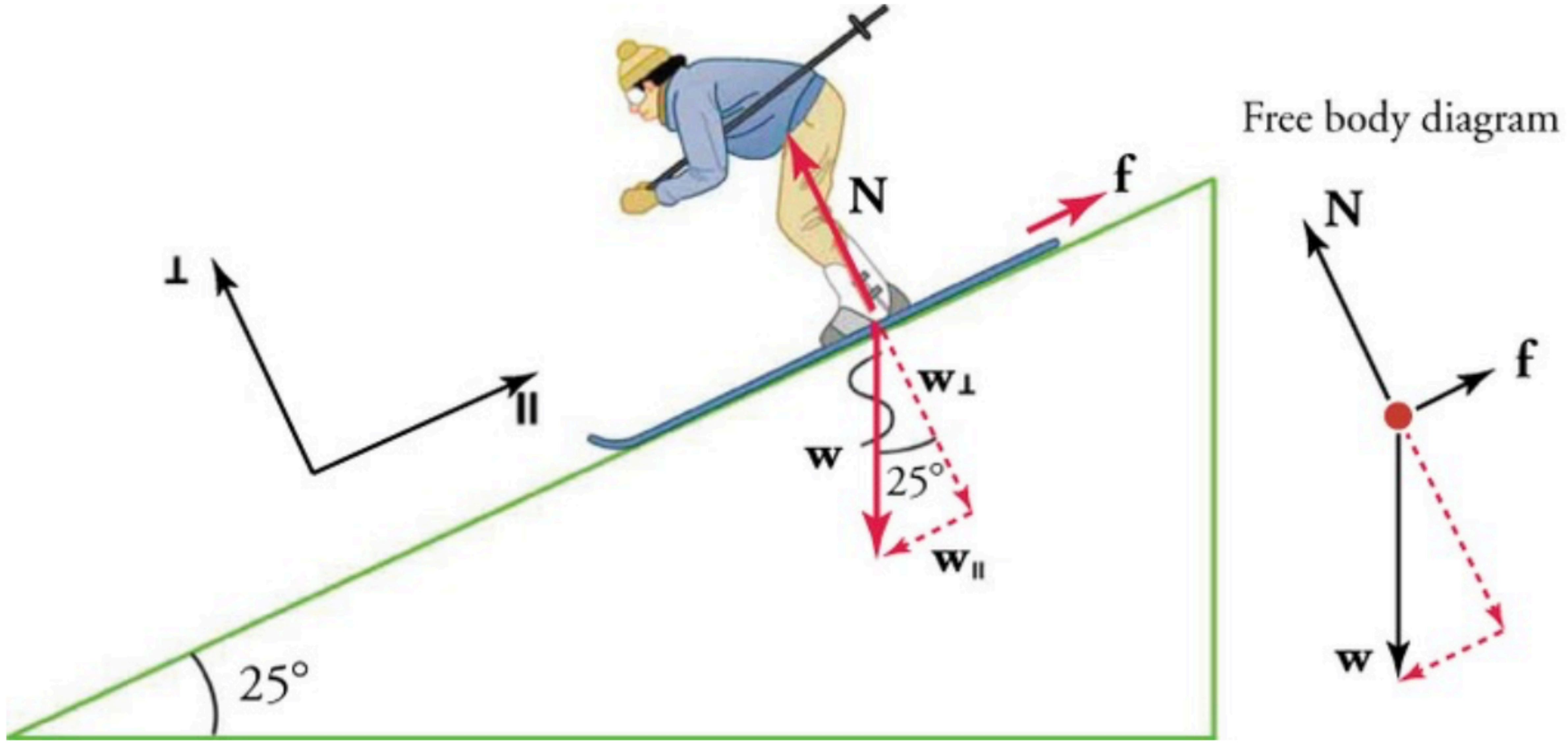
2) 8.13 m/s^2

d) 1) 8.88 m/s^2

2) 8.13 m/s^2

A B C D E

CQ.4.5



The skier's mass including equipment is $60.0\,\mathrm{kg}$. 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 $45.0\,\mathrm{N}$?

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

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

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 $a_{||} = \frac{F_{\mathrm{net}||}}{m}$

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

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

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

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

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

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

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

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

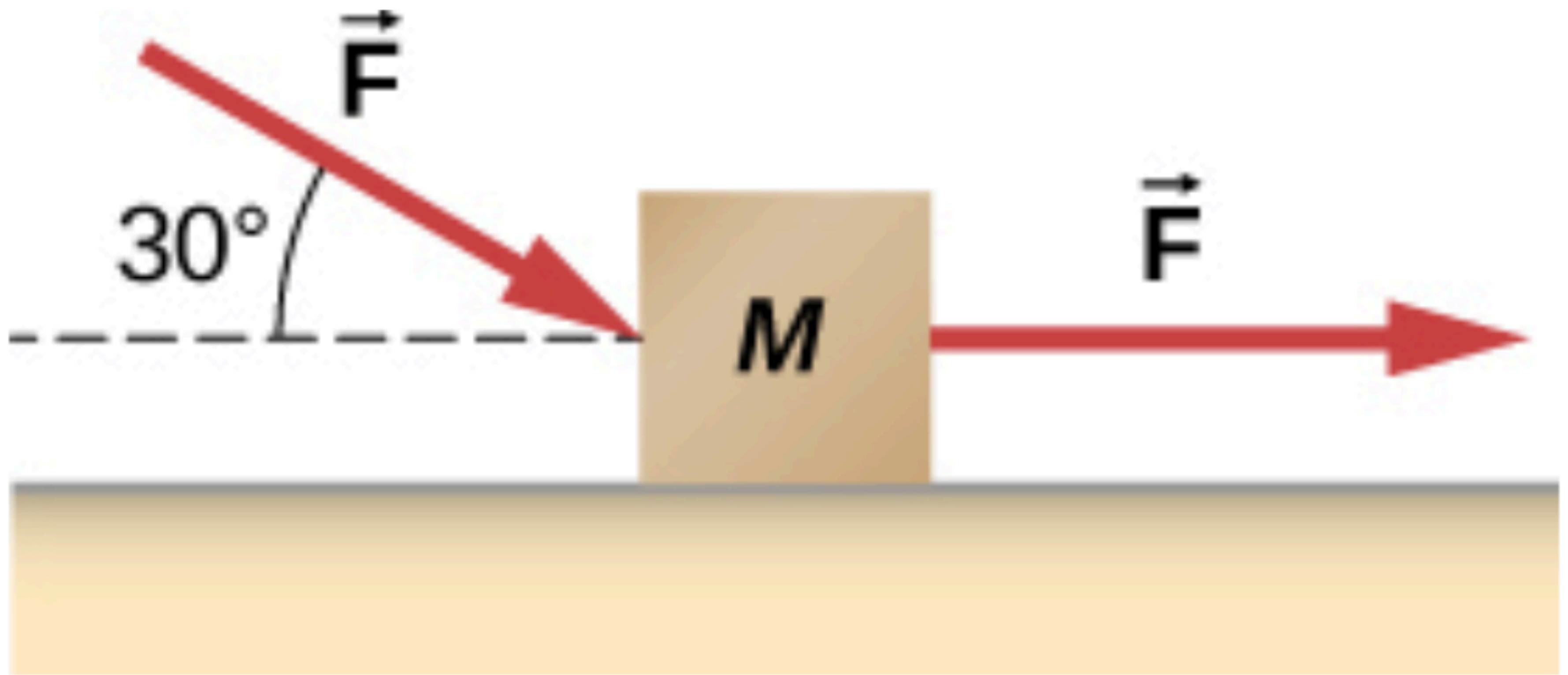
The perpendicular component of the weight will not appear in the equation of motion of the skier. Also, reconsider the parallel component of the weight, $mg\sin\theta$.

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 $a_{||} = \frac{F_{net||}}{m}$

A B C D E

Activity:
Worked Problem

40 . In the following figure, the horizontal surface on which this block slides is frictionless. If the two forces acting on it each have magnitude $F = 30.0\,\mathrm{N}$ and $M = 10.0\,\mathrm{kg}$, what is the magnitude of the resulting acceleration of the block?



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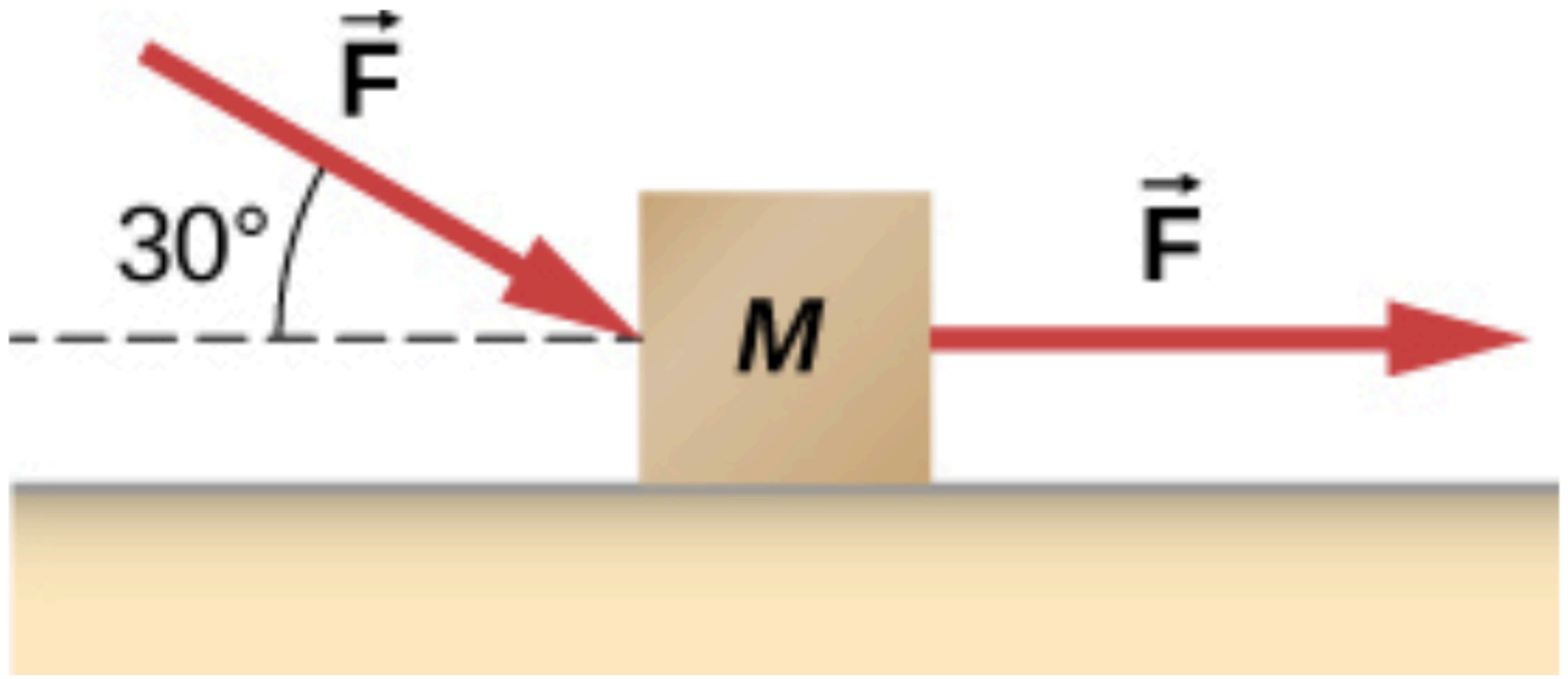
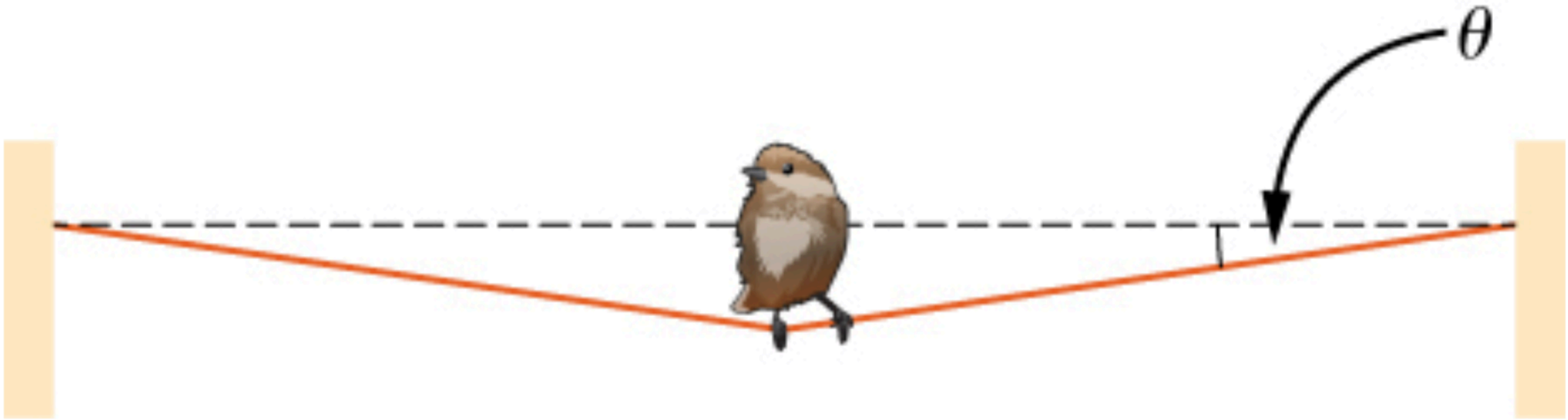


Solution

$5.60\ \mathrm{m/s^2}$

WP 5.3

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.



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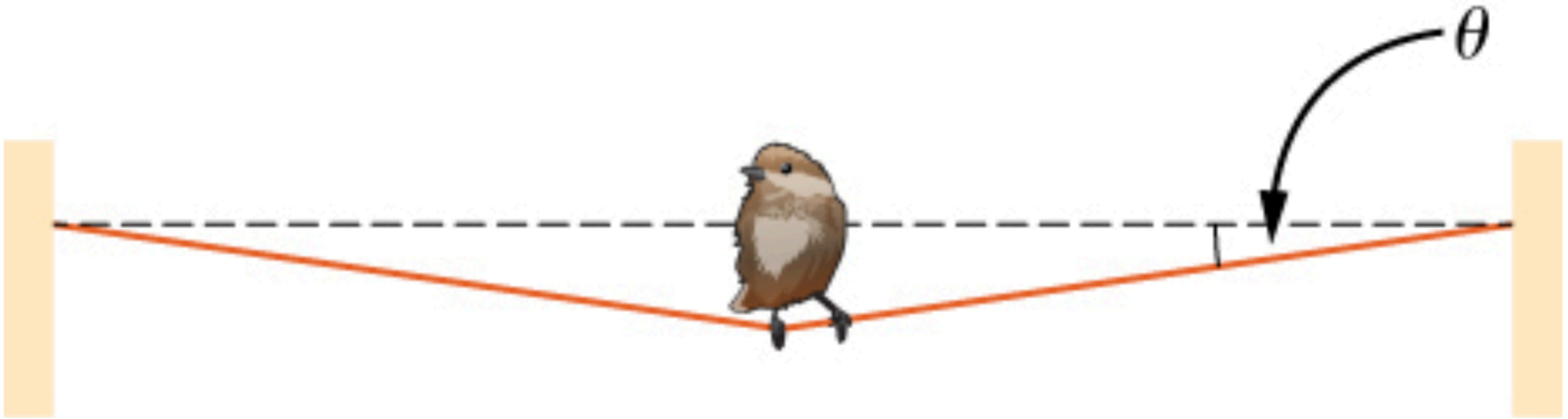

b. 1.5 N; c. 15 N

See you next class!

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