Physics 111 - Class 7A
Force Applications

October 17, 2022

Class Outline

- Logistics / Announcements
- Mid-course Feedback Results
- Introduction to Chapter 6
- Clicker Questions
- Activity: Worked Problems

Logistics/Announcements

- Lab this week: Lab 4
- HW6 due this week on Thursday at 6 PM
- Learning Log 6 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Bonus Test 2 available this week (Chapters 3 & 4)
- Additional Student Hours from Tutorial TAs for more 1:1 help via Zoom

Mid-course Feedback Results

Phys 111 2022WT1 Mid-course feedback

Default Question Block

Q2

What do you think of the course structure so far?

Reminder: the course structure is: Watch videos before class, attempt HW problems throughout the week, in Lectures you practice working with the most complex topics, and learn some practical skills during lab. Tests and Bonus Tests are held every two weeks keeps the content fresh in your mind, and reflections in Learning Logs cap off the week of learning.

- 173 respondents ~ 60% response rate (class of 289)
  - Thank you for taking the time to submit the feedback!

Monday's Class

6.1 Solving problems with Newton's Laws
6.2 Friction

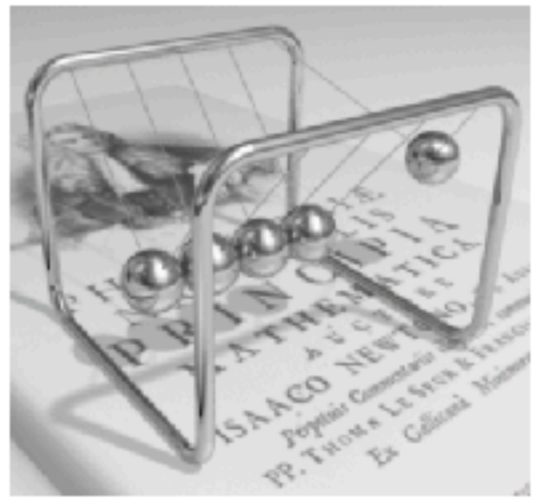
Preface
Mechanics
1 Units and Measurement
2 Vectors
3 Motion Along a Straight Line
4 Motion in Two and Three Dimensions
5 Newton's Laws of Motion
6 Applications of Newton's Laws
Introduction
6.1 Solving Problems with Newton's Laws
6.2 Friction
6.3 Centripetal Force
6.4 Drag Force and Terminal Speed
Chapter Review
7 Work and Kinetic Energy
8 Potential Energy and Conservation of Energy
9 Linear Momentum and Collisions
10 Fixed-Axis Rotation
11 Angular Momentum
12 Static Equilibrium and Elasticity

Figure 6.1 Stock cars racing in the Grand National Divisional race at Iowa Speedway in May, 2015. Cars often reach speeds of 200 mph (320 km/h). (credit: modification of work by Erik Schneider/U.S. Navy)

Chapter Outline

6.1 Solving Problems with Newton's Laws
6.2 Friction
6.3 Centripetal Force
6.4 Drag Force and Terminal Speed

Car racing has grown in popularity in recent years. As each car moves in a curved path around the turn, its wheels also spin rapidly. The wheels complete many revolutions while the car makes only part of one (a circular arc). How



Physics 111

Search this book...

Unsyllabus

ABOUT THIS COURSE

Course Syllabus (Official)
Course Schedule
Accommodations
How to do well in this course

GETTING STARTED

Before the Term starts
After the first class
In the first week
Week 1 - Introductions!

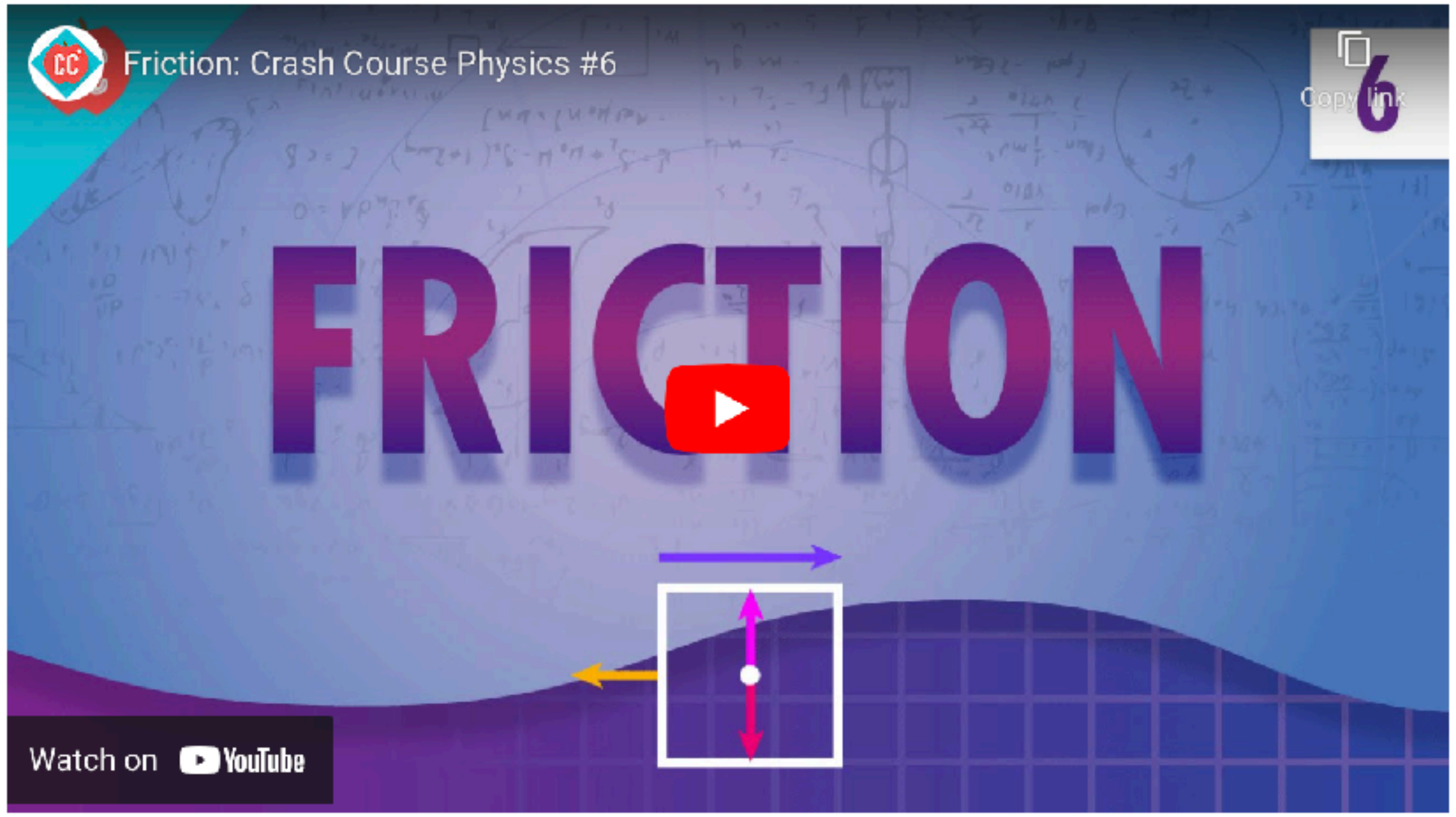
PART 1 - KINEMATICS

Week 2 - Chapter 2
Week 3 - Chapter 3
Week 4 - Chapter 4

PART 2 - DYNAMICS

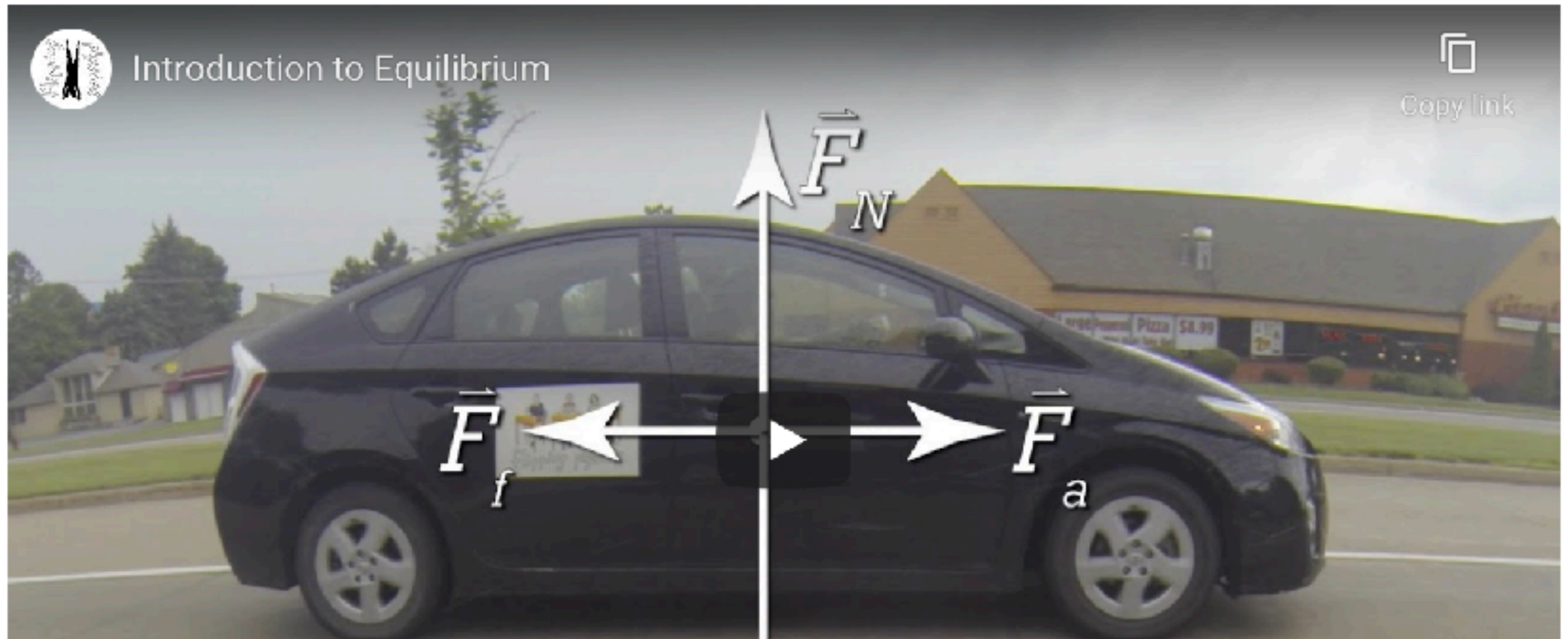
Week 5 - Chapter 5
Week 6 - Week Off !!
Week 7 - Chapter 6
- Readings
- Videos
- Homework
- Tutorial

Friction



Required Videos

1. Introduction to Equilibrium



Video 2
Video 3
Video 4
Video 5
Video 6
Video 7
Video 8
Video 9
Video 10
Video 11
Video 12

Applications of Newton's Laws

- Before the break, we discussed Newton's Three Laws, the concept of a "Free Body Diagram", and splitting forces into its vector components.
- This week, we will look at solving some physics problems with those concepts!
- It's important to note that there is no "new physics" this week! All of the problems we solve will just be applying Newton's Laws in different contexts

Components of Forces

$$\sum F_{net,x} = ma_x$$

$$\sum F_{net,y} = ma_y$$

No matter how complex the problem seems, this always holds true!

CQ7.0A - Classic Elevator Problems

A person is standing in an elevator on top of a weighing scale. The person has a mass of 60kg. Assume $g = 10\mathrm{m/s^2}$

What is the reading on the scale (in N)?

A) 720 N

B) 600 N

C) 480 N

D) 400 N

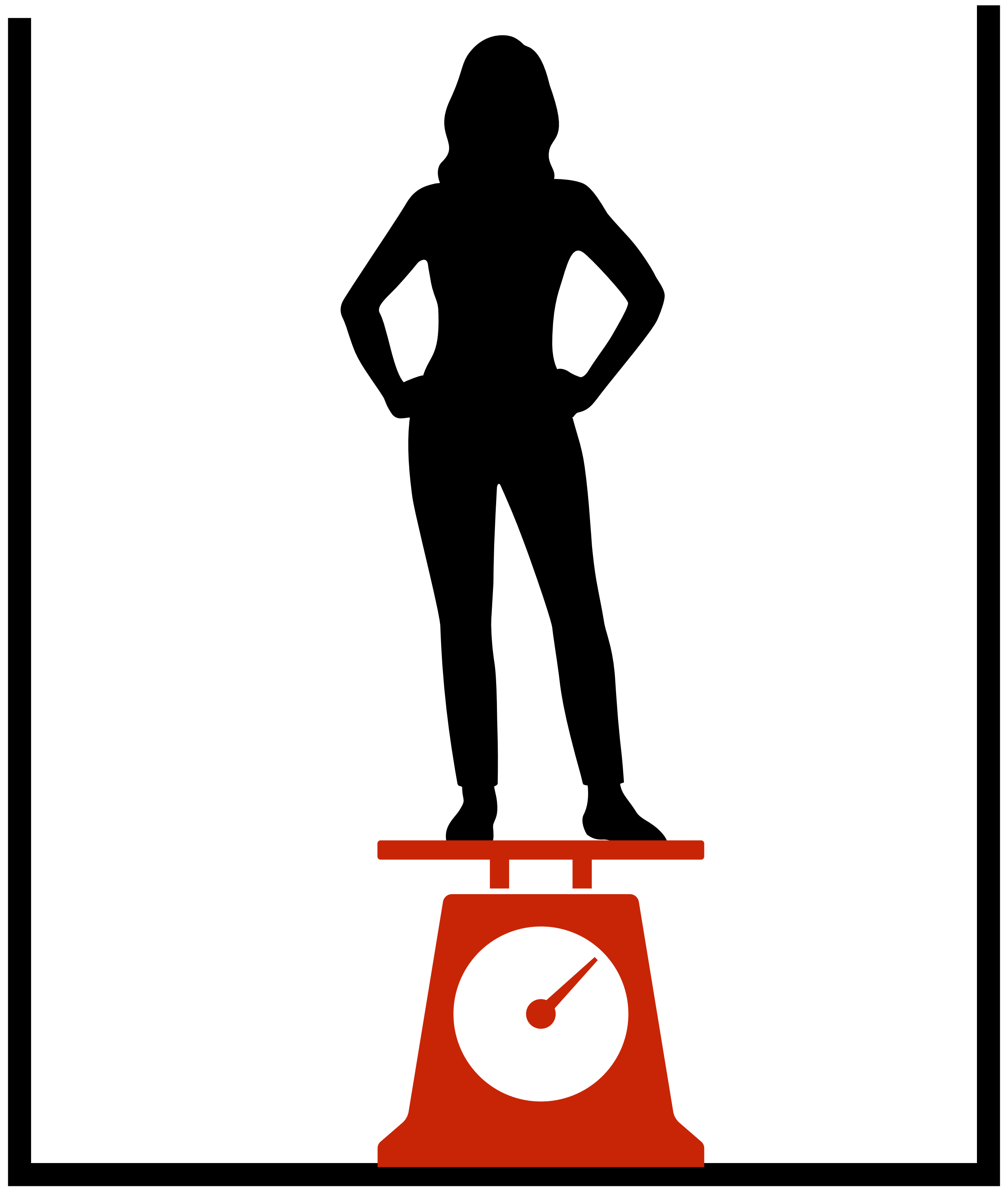
E) 0 N

F) I don't know

Elevator at rest

$$\vec{a} = 0$$

$$\vec{v} = 0$$



CQ7.0B - Classic Elevator Problems

A person is standing in an elevator on top of a weighing scale. The person has a mass of 60kg. Assume $g = 10\mathrm{m/s^2}$

What is the reading on the scale (in N)?

A) 720 N

B) 600 N

C) 480 N

D) 400 N

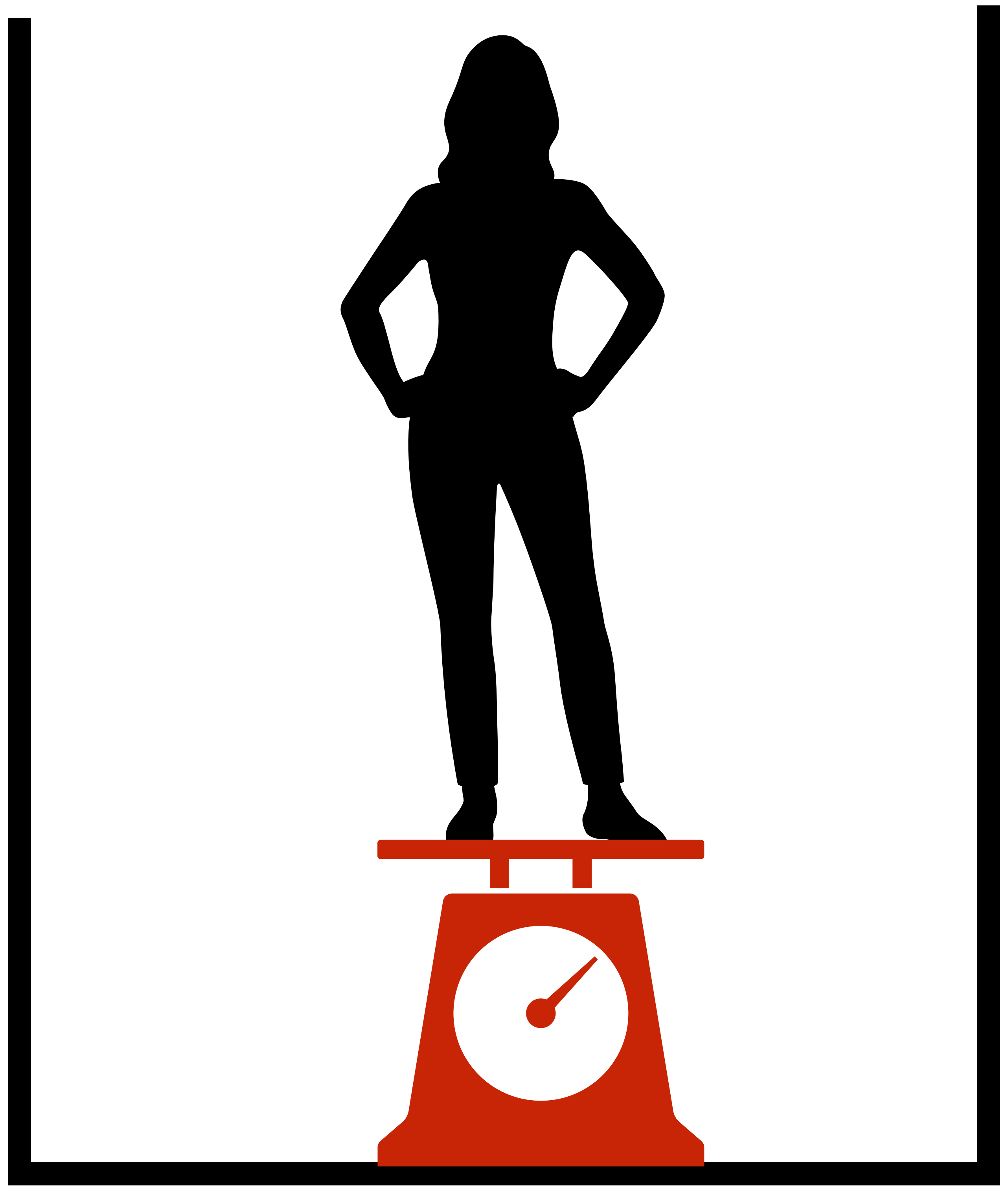
E) 0 N

F) I don't know

Elevator moving up

$$\vec{a} = 0$$

$$\vec{v} = 3m/s$$



A person is standing in an elevator on top of a weighing scale. The person has a mass of 60kg. Assume $g = 10\text{m/s}^2$

What is the reading on the scale (in N)?

A) 720 N

B) 600 N

C) 480 N

D) 400 N

E) 0 N

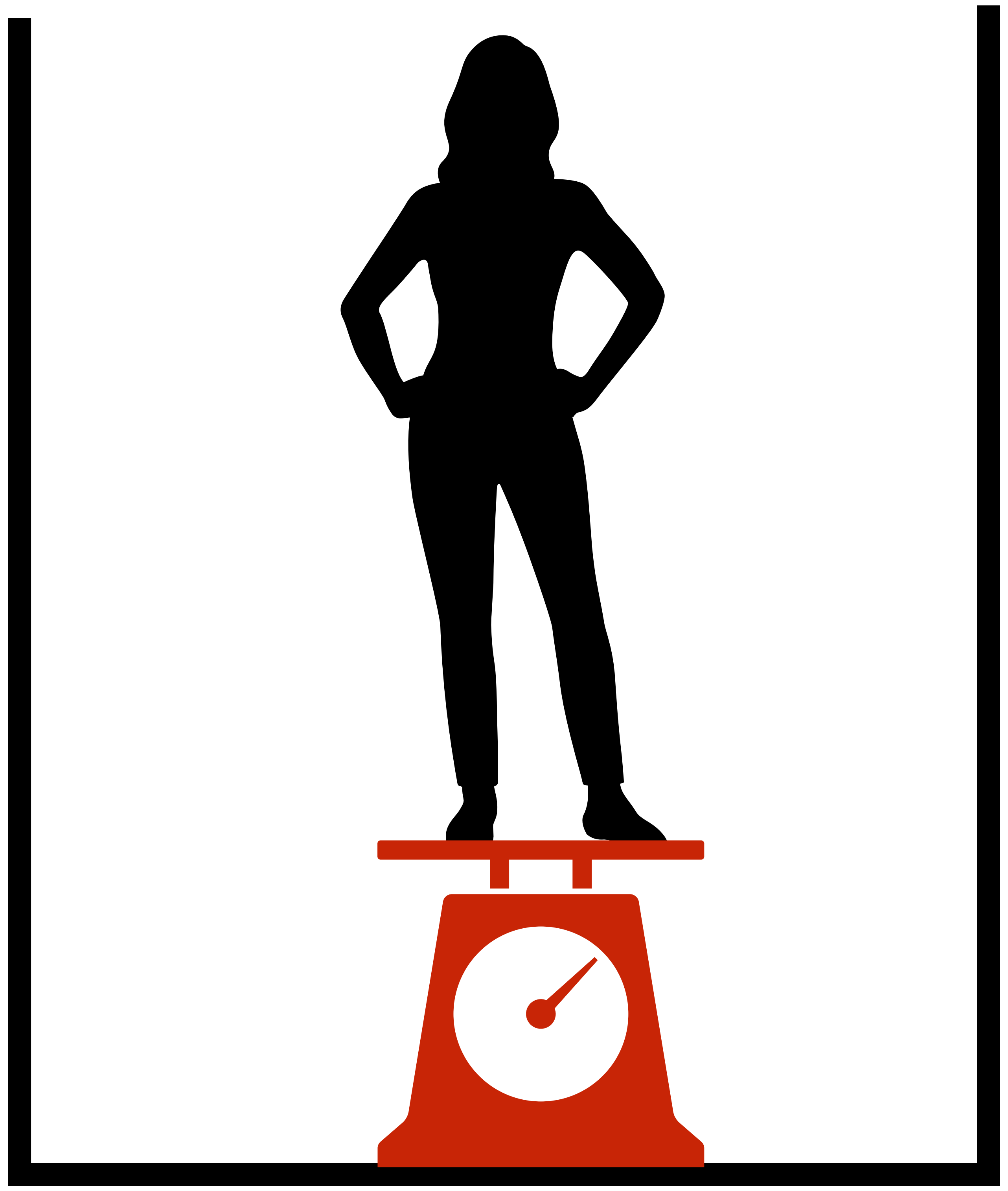
F) I don't know

CQ7.0C - Classic Elevator Problems

Elevator accelerating UP

$$\vec{a} = 2\,\text{m/s}^2$$

$$\vec{v} = \text{variable}$$



A person is standing in an elevator on top of a weighing scale. The person has a mass of 60kg. Assume $g = 10\mathrm{m/s}^2$

What is the reading on the scale (in N)?

A) 720 N

B) 600 N

C) 480 N

D) 400 N

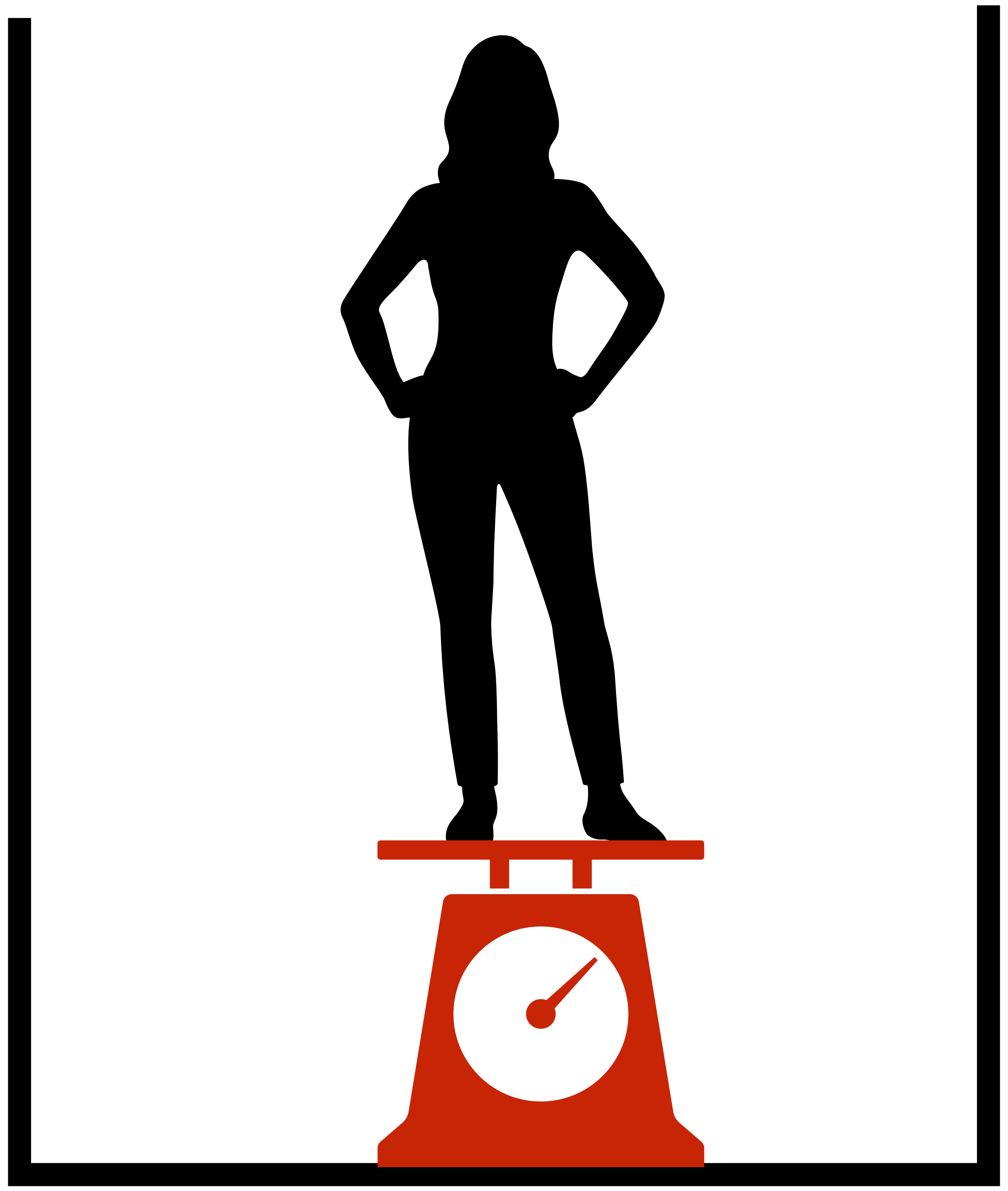
E) 0 N

F) I don't know

Elevator accelerating down

$\vec{a} = 2m/s^2$

$\vec{v} =$ variable



CQ7.0E - Classic Elevator Problems

A person is standing in an elevator on top of a weighing scale. The person has a mass of 60kg. Assume $g = 10\mathrm{m/s^2}$

What is the reading on the scale (in N)?

A) 720 N

B) 600 N

C) 480 N

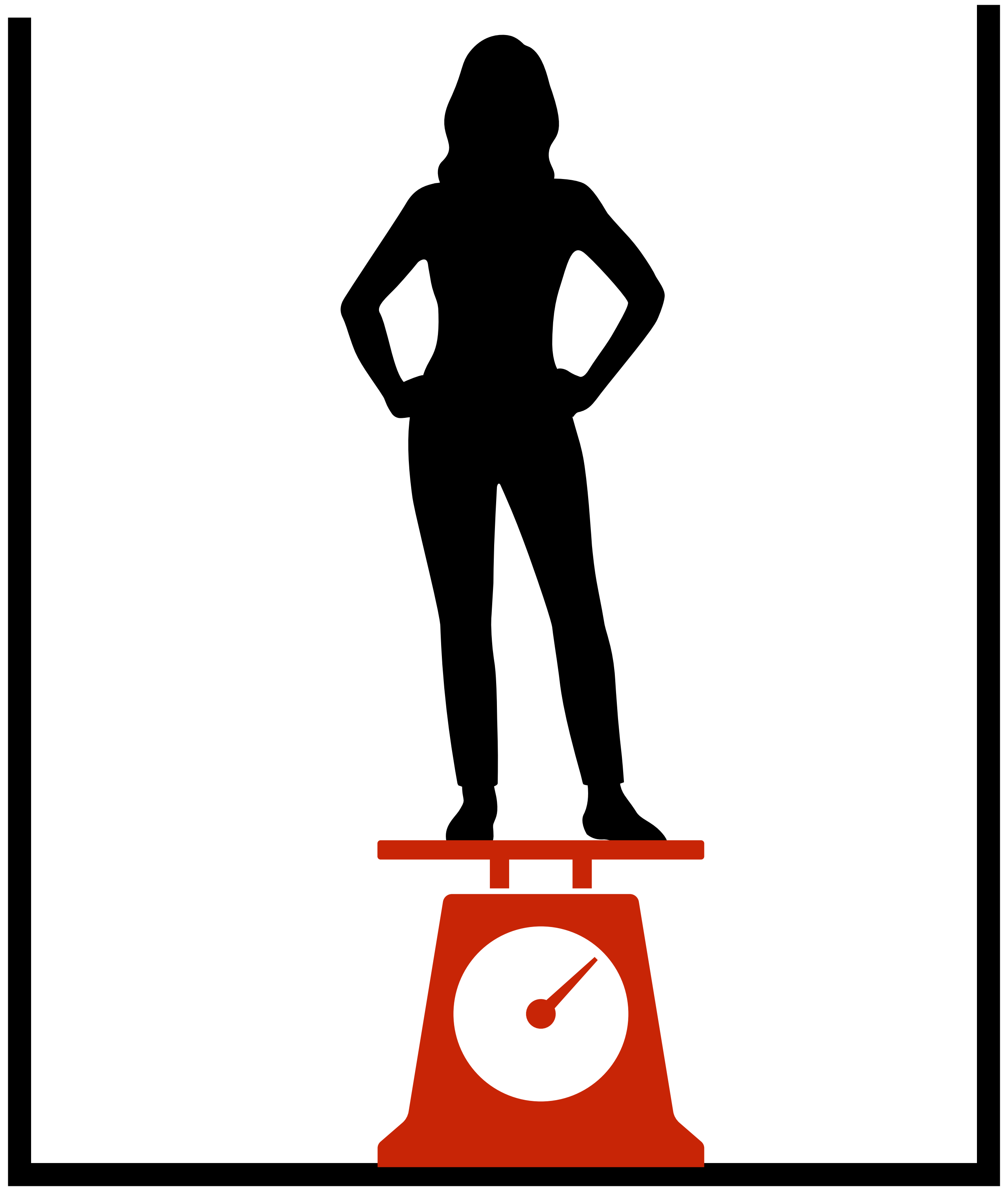
D) 400 N

E) 0 N

F) I don't know

Elevator cable is cut!

$$\vec{a} = ?(\text{pain})$$
$$\vec{v} = ?(\text{fast})$$



Textbook Examples

EXAMPLE 6.1

Different Tensions at Different Angles

EXAMPLE 6.2

Drag Force on a Barge

EXAMPLE 6.3

What Does the Bathroom Scale Read in an Elevator?

EXAMPLE 6.4

Two Attached Blocks

EXAMPLE 6.5

Atwood Machine

EXAMPLE 6.6

What Force Must a Soccer Player Exert to Reach Top Speed?

EXAMPLE 6.7

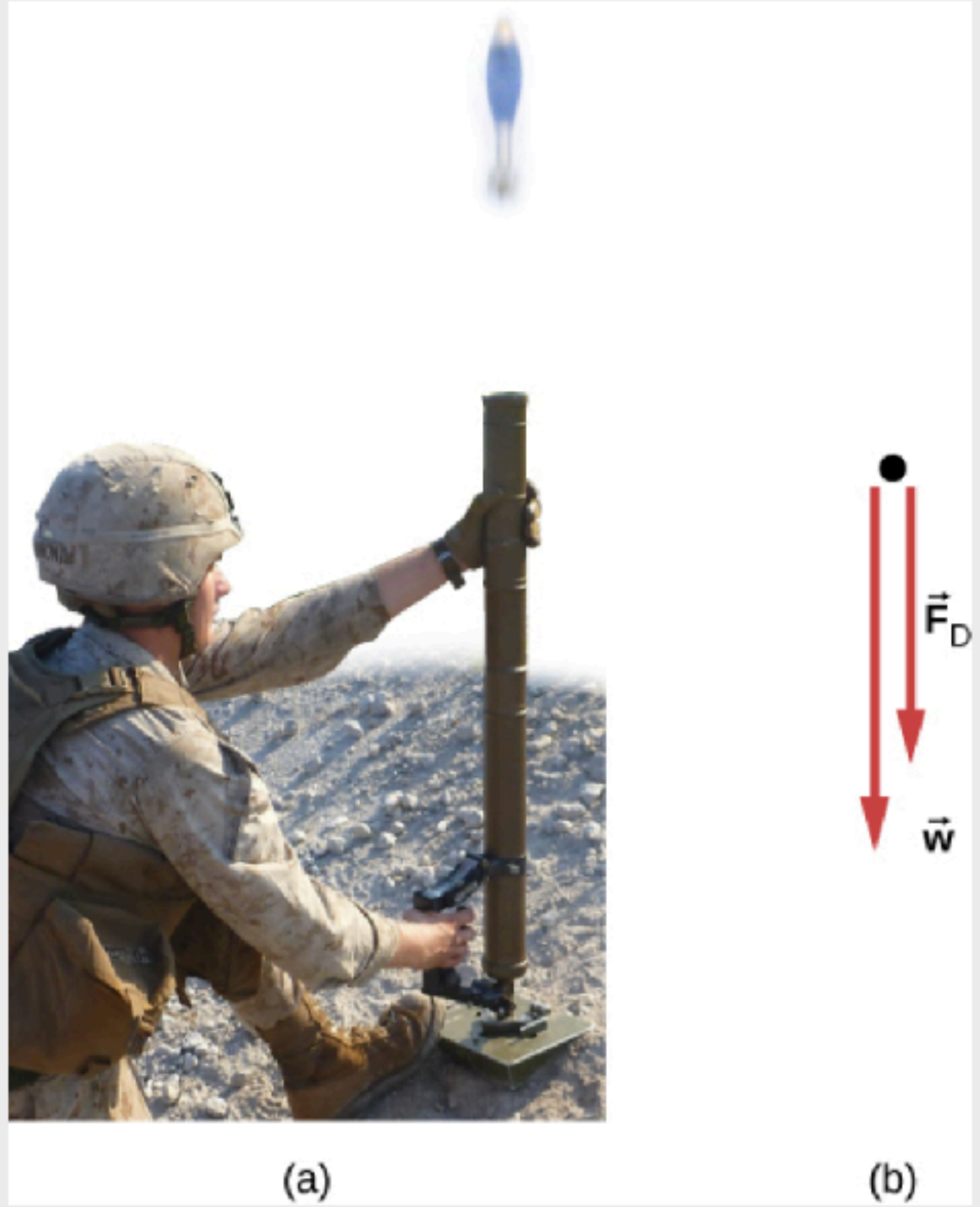
What Force Acts on a Model Helicopter?

Textbook Examples (requires Integration)

EXAMPLE 6.9

Motion of a Projectile Fired Vertically

A 10.0-kg mortar shell is fired vertically upward from the ground, with an initial velocity of 50.0 m/s (see Figure 6.9). Determine the maximum height it will travel if atmospheric resistance is measured as $F_D = (0.0100v^2)$ N, where v is the speed at any instant.



EXAMPLE 6.8

Baggage Tractor

Figure 6.8(a) shows a baggage tractor pulling luggage carts from an airplane. The tractor has mass 650.0 kg, while cart A has mass 250.0 kg and cart B has mass 150.0 kg. The driving force acting for a brief period of time accelerates the system from rest and acts for 3.00 s. (a) If this driving force is given by $F = (820.0t)$ N, find the speed after 3.00 seconds. (b) What is the horizontal force acting on the connecting cable between the tractor and cart A at this instant?

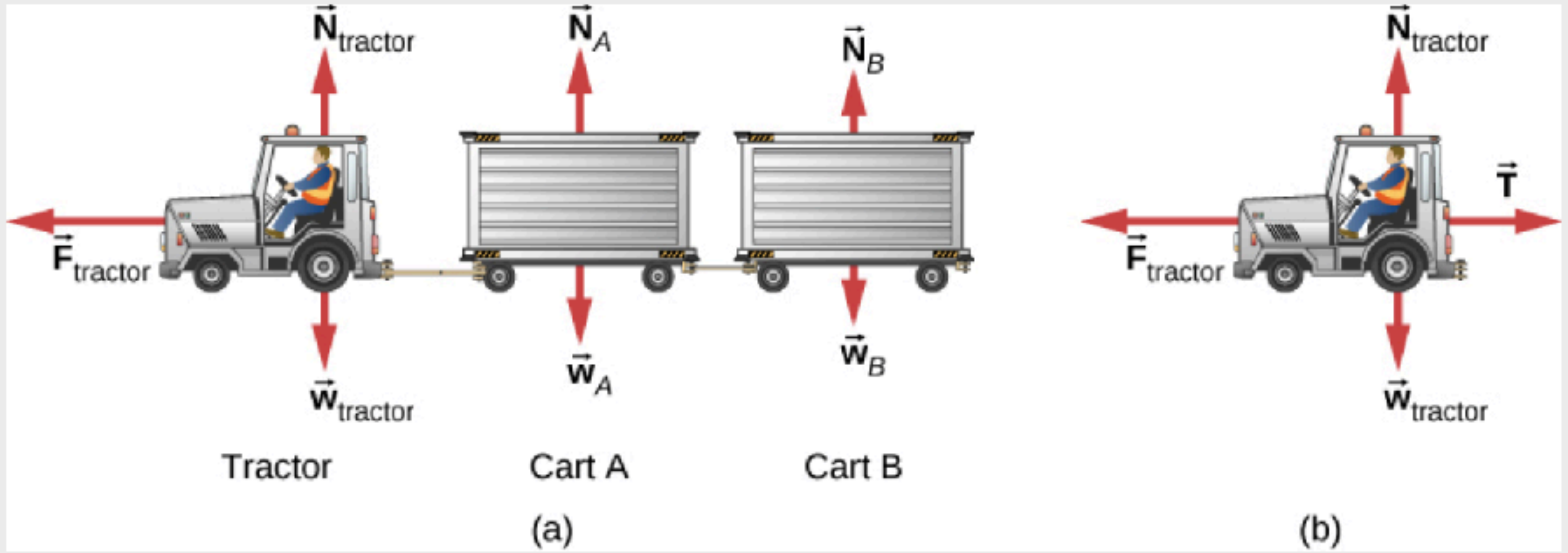


Figure 6.8 (a) A free-body diagram is shown, which indicates all the external forces on the system consisting of the tractor and baggage carts for carrying airline luggage. (b) A free-body diagram of the tractor only is shown isolated in order to calculate the tension in the cable to the carts.

Friction

FRICTION

Friction is a force that opposes relative motion between systems in contact.

STATIC AND KINETIC FRICTION

If two systems are in contact and stationary relative to one another, then the friction between them is called **static friction**. If two systems are in contact and moving relative to one another, then the friction between them is called **kinetic friction**.

Friction

MAGNITUDE OF STATIC FRICTION

The magnitude of static friction f_s is

$$f_s \leq \mu_s N, \tag{6.1}$$

where μ_s is the coefficient of static friction and N is the magnitude of the normal force.

The symbol $\leq$ means *less than or equal to*, implying that static friction can have a maximum value of $\mu_s N$. Static friction is a responsive force that increases to be equal and opposite to whatever force is exerted, up to its maximum limit. Once the applied force exceeds

$f_s(\text{max})$, the object moves. Thus,

$$f_s(\text{max}) = \mu_s N.$$

Friction

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MAGNITUDE OF KINETIC FRICTION

The magnitude of kinetic friction f_k is given by

$$f_k = \mu_k N, \tag{6.2}$$

where μ_k is the coefficient of kinetic friction.

Friction

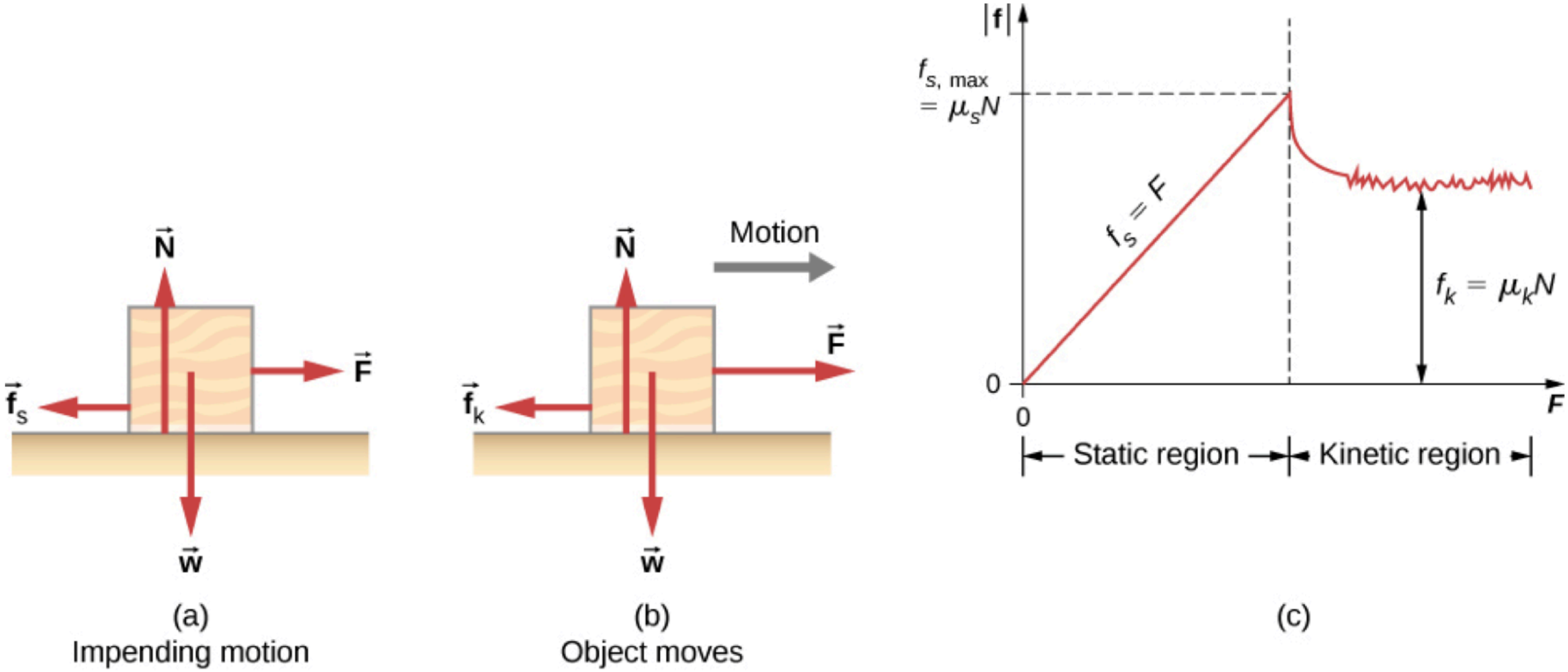


Figure 6.11 (a) The force of friction $\vec{\mathbf{f}}$ between the block and the rough surface opposes the direction of the applied force $\vec{\mathbf{F}}$. The magnitude of the static friction balances that of the applied force. This is shown in the left side of the graph in (c). (b) At some point, the magnitude of the applied force is greater than the force of kinetic friction, and the block moves to the right. This is shown in the right side of the graph. (c) The graph of the frictional force versus the applied force; note that $f_s(\text{max}) > f_k$. This means that $\mu_s > \mu_k$.

Friction

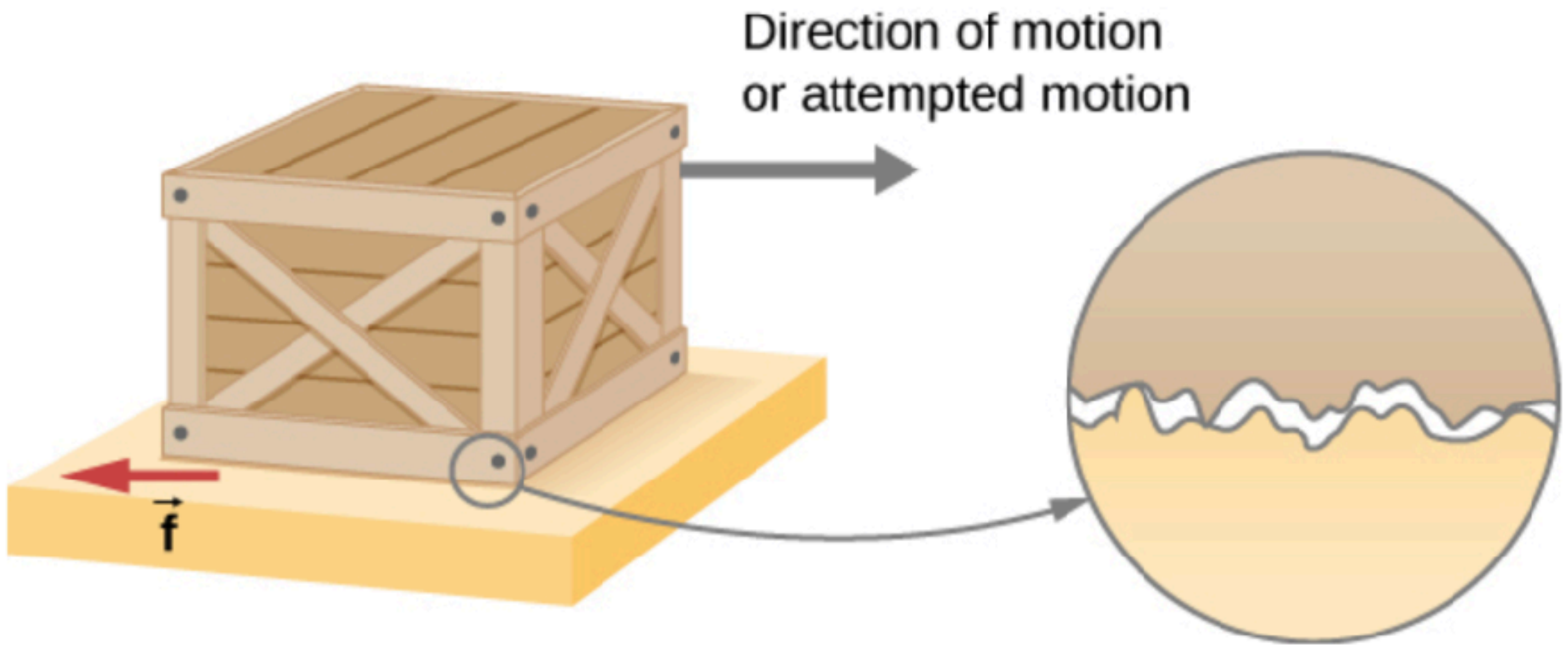


Figure 6.10 Frictional forces, such as $\vec{\mathbf{f}}$, always oppose motion or attempted motion between objects in contact. Friction arises in part because of the roughness of the surfaces in contact, as seen in the expanded view. For the object to move, it must rise to where the peaks of the top surface can skip along the bottom surface. Thus, a force is required just to set the object in motion. Some of the peaks will be broken off, also requiring a force to maintain motion. Much of the friction is actually due to attractive forces between molecules making up the two objects, so that even perfectly smooth surfaces are not friction-free. (In fact, perfectly smooth, clean surfaces of similar materials would adhere, forming a bond called a “cold weld.”)

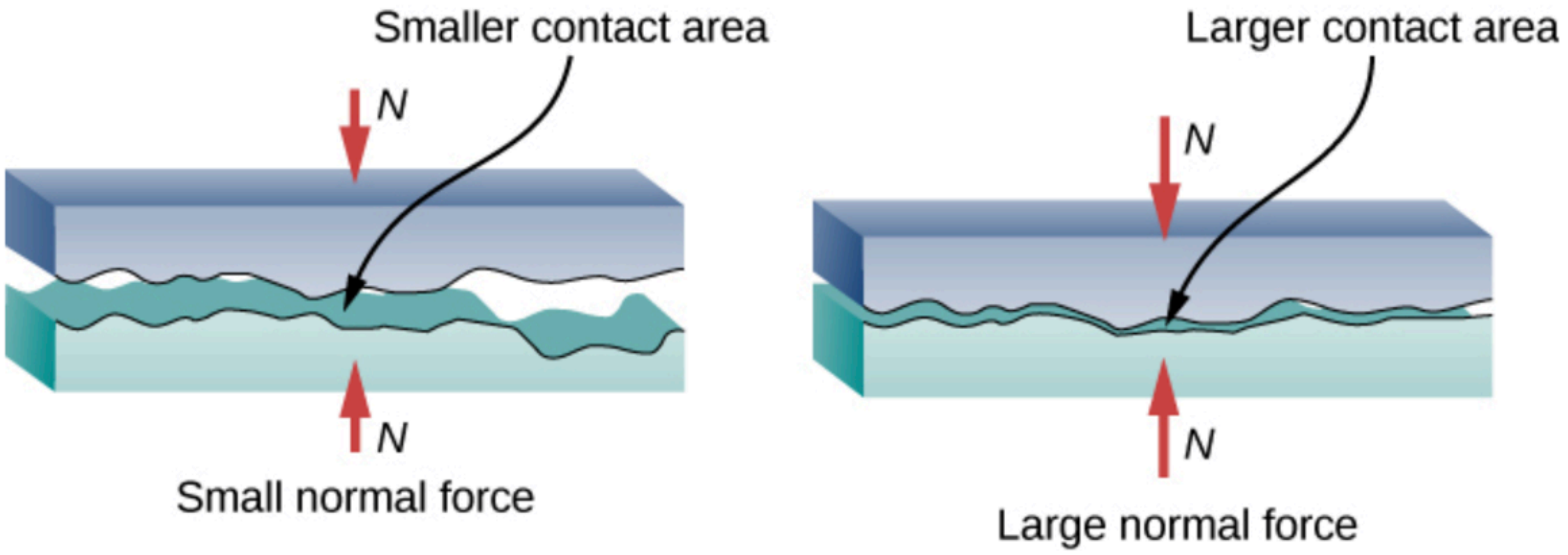


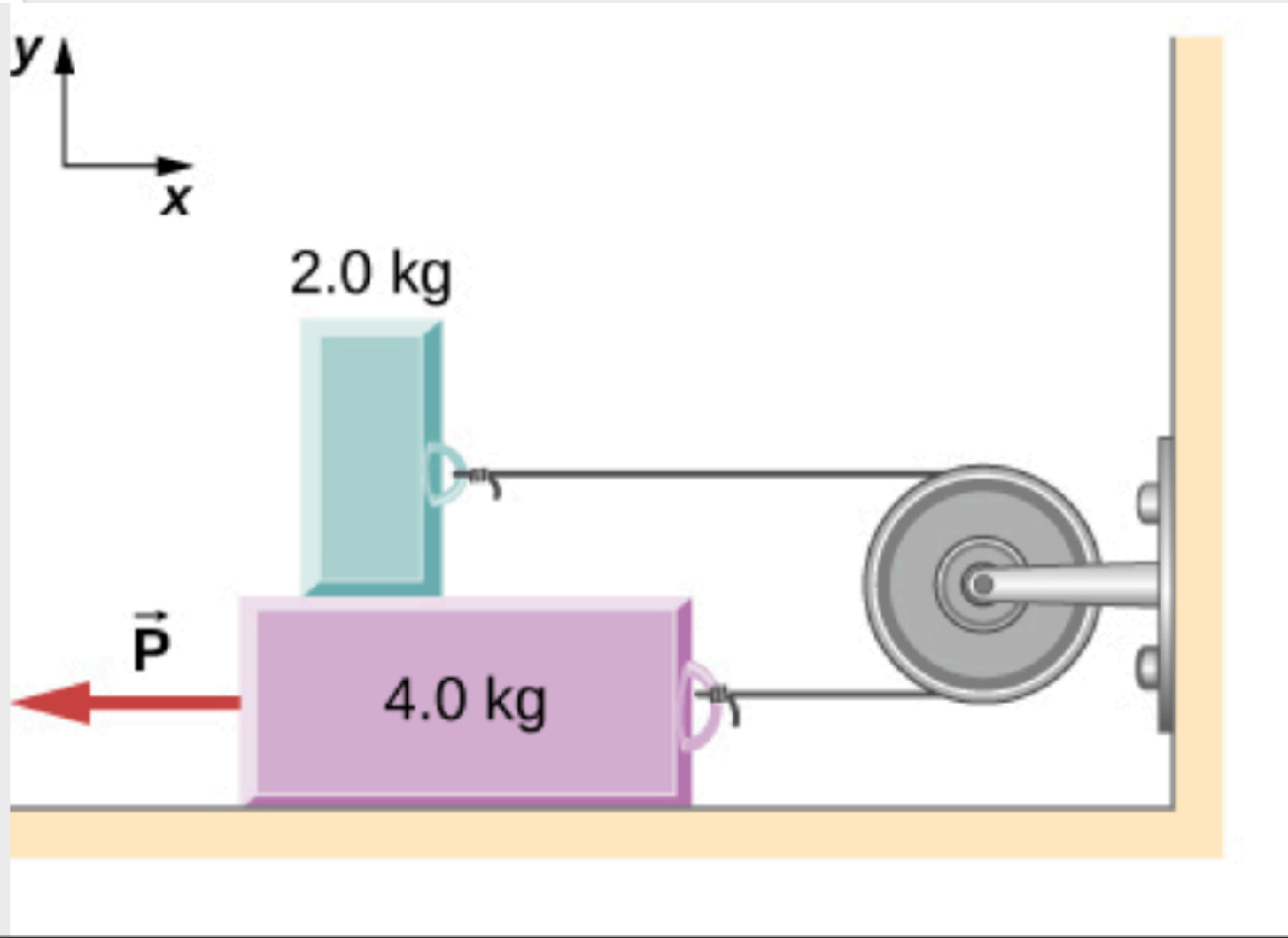
Figure 6.15 Two rough surfaces in contact have a much smaller area of actual contact than their total area. When the normal force is larger as a result of a larger applied force, the area of actual contact increases, as does friction.

Friction

EXAMPLE 6.12

Sliding Blocks

The two blocks of Figure 6.17 are attached to each other by a massless string that is wrapped around a frictionless pulley. When the bottom 4.00-kg block is pulled to the left by the constant force $\vec{\mathbf{P}}$, the top 2.00-kg block slides across it to the right. Find the magnitude of the force necessary to move the blocks at constant speed. Assume that the coefficient of kinetic friction between all surfaces is 0.400.



Friction

EXAMPLE 6.12

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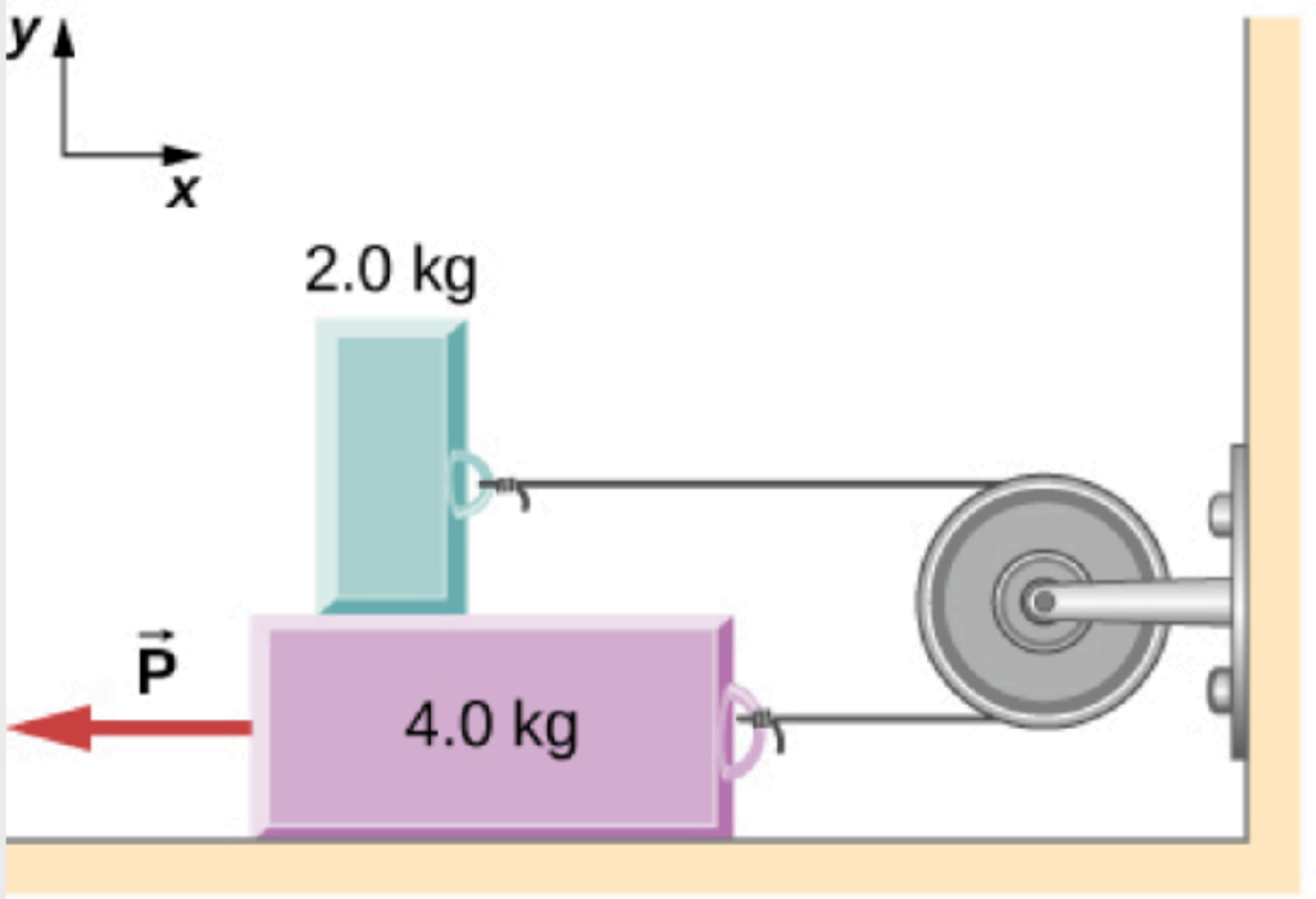


Strategy

We analyze the motions of the two blocks separately. The top block is subjected to a contact force exerted by the bottom block. The components of this force are the normal force N_1 and the frictional force $-0.400N_1$. Other forces on the top block are the tension $T\mathbf{i}$ in the string and the weight of the top block itself, 19.6 N. The bottom block is subjected to contact forces due to the top block and due to the floor. The first contact force has components $-N_1$ and $0.400N_1$, which are simply reaction forces to the contact forces that the bottom block exerts on the top block. The components of the contact force of the floor are N_2 and $0.400N_2$. Other forces on this block are $-P$, the tension $T\mathbf{i}$, and the weight –39.2 N.

Solution

Since the top block is moving horizontally to the right at constant velocity, its acceleration is zero in both the horizontal and the vertical directions. From Newton's second law,

$$\begin{aligned} \sum F_x &= m_1 a_x & \qquad \sum F_y &= m_1 a_y \\ T - 0.400N_1 &= 0 & N_1 - 19.6\,\text{N} &= 0. \end{aligned}$$

Solving for the two unknowns, we obtain $N_1 = 19.6\,\text{N}$ and $T = 0.40N_1 = 7.84\,\text{N}$. The bottom block is also not accelerating, so the application of Newton's second law to this block gives

$$\begin{aligned} &\sum F_x = m_2 a_x & \qquad &\sum F_y = m_2 a_y \\ &T - P + 0.400\,N_1 + 0.400\,N_2 = 0 & &N_2 - 39.2\,\text{N} - N_1 = 0. \end{aligned}$$

The values of N_1 and T were found with the first set of equations. When these values are substituted into the second set of equations, we can determine N_2 and P. They are

$$N_2 = 58.8\,\text{N} \quad \text{and} \quad P = 39.2\,\text{N}.$$

Spring Force

Spring force

A spring is a special medium with a specific atomic structure that has the ability to restore its shape, if deformed. To restore its shape, a spring exerts a restoring force that is proportional to and in the opposite direction in which it is stretched or compressed. This is the statement of a law known as Hooke's law, which has the mathematical form

$$\vec{\mathbf{F}} = -k\vec{\mathbf{x}}.$$

The constant of proportionality k is a measure of the spring's stiffness. The line of action of this force is parallel to the spring axis, and the sense of the force is in the opposite direction of the displacement vector (Figure 5.29). The displacement must be measured from the relaxed position; $x = 0$ when the spring is relaxed.

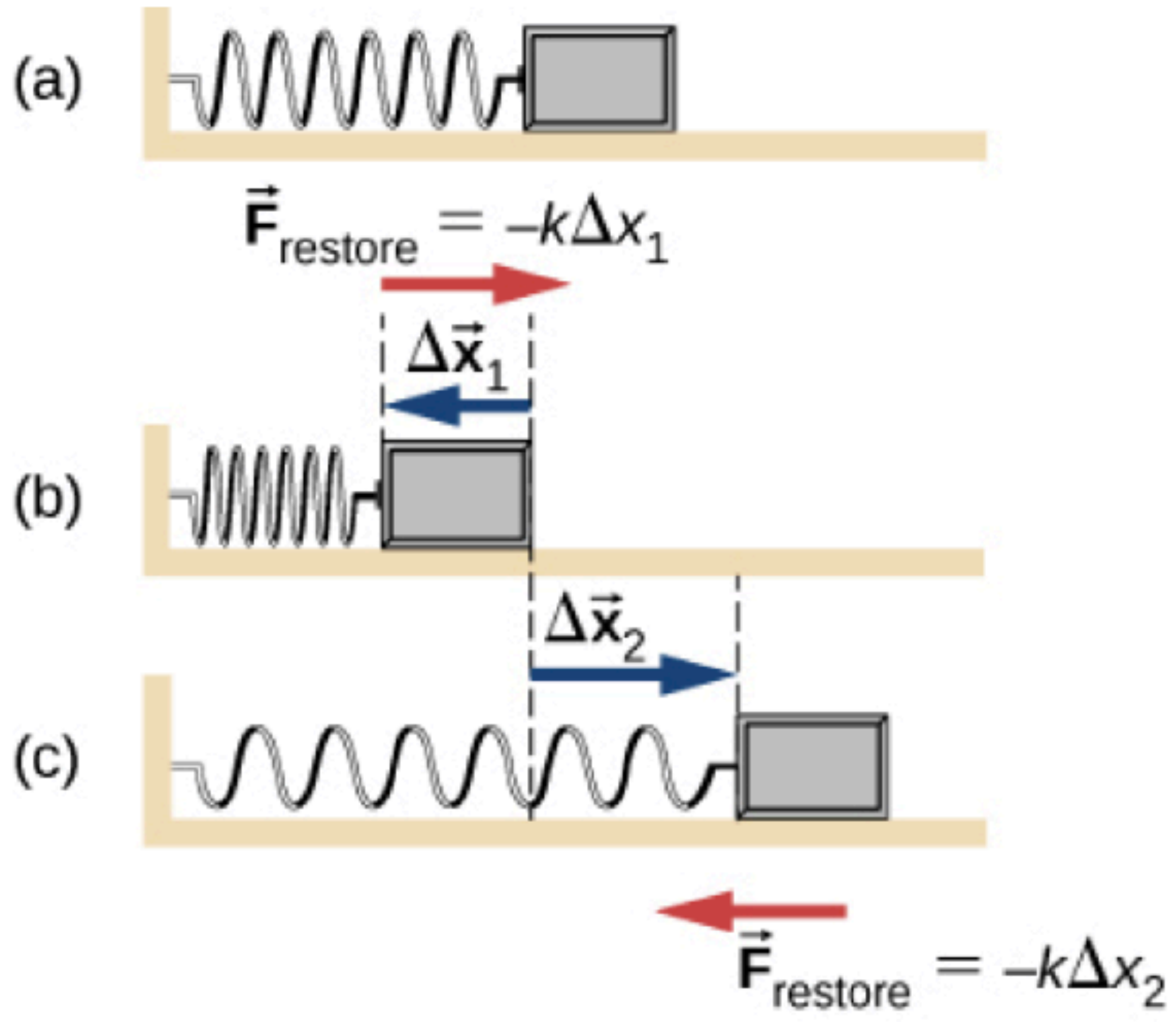


Figure 5.29 A spring exerts its force proportional to a displacement, whether it is compressed or stretched. (a) The spring is in a relaxed position and exerts no force on the block. (b) The spring is compressed by displacement $\Delta\vec{\mathbf{x}}_1$ of the object and exerts restoring force $-k\Delta\vec{\mathbf{x}}_1$. (c) The spring is stretched by displacement $\Delta\vec{\mathbf{x}}_2$ of the object and exerts restoring force $-k\Delta\vec{\mathbf{x}}_2$.

Key Equations

Magnitude of static friction	$f_s \leq \mu_s N$
Magnitude of kinetic friction	$f_k = \mu_k N$
Centripetal force	$F_c = m\frac{v^2}{r}$ or $F_c = mr\omega^2$
Ideal angle of a banked curve	$\tan\theta = \frac{v^2}{rg}$
Drag force	$F_D = \frac{1}{2}C\rho Av^2$
Stokes' law	$F_s = 6\pi r\eta v$

Clicker Questions

CQ.7.1

A 1100-kg car pulls a boat on a trailer.

What total frictional force resists the motion of the car, boat, and trailer, if the car exerts a 1900-N force on the road and produces an acceleration of $0.550\ \mathrm{m/s^2}$? The mass of the boat plus trailer is $700 kg$.

a) 1300 N

b) 1900 N

c) 1520 N

d) 910 N

A B C D E

CQ.7.2

A flea jumps by exerting a force of 1.20×10^{-5} N straight down on the ground. A breeze blowing on the flea parallel to the ground exerts a force of 0.500×10^{-6} N on the flea. Find the direction and magnitude of the acceleration of the flea if its mass is 6.00×10^{-7} kg. Do not neglect the gravitational force.

a) 20.0 m/s^2, 2.39° from vertical

b) 10.2 m/s^2, 2.39° above horizontal

c) 10.2 m/s^2, 4.67° from vertical

d) 20.0 m/s^2, 4.67° from vertical

A B C D E

CQ.7.3

A skier with a mass of 67 kg is skiing down a snowy slope with an incline of 37° . Find the friction if the coefficient of kinetic friction (μ_k) is 0.07. (Take Earth's gravity as 9.8 m/s^2)

a) 27.7 N

b) 34.7 N

c) 36.7 N

d) 46.0 N

A B C D E

CQ.7.4

Two springs are attached to two hooks. Spring A has a greater force constant than spring B. Equal weights are suspended from both. Which of the following statements is true?

a) Spring A will have more extension than spring B.

b) Spring B will have more extension than spring A.

c) Both springs will have same extension.

d) Both springs are equally stiff.

A B C D E

CQ.7.5

A team of six dogs pulls a sled with waxed wood runners on wet snow (μ_k = 0.08). The loaded sled with its rider has a mass of 210 kg.

If each dog exerts an average force of 35 N applied force, what is the acceleration of the sled? (Take Earth's gravity as 9.8 m/s^2

a) 0.22 m/s^2

b) 0.46 m/s^2

c) 0.78 m/s^2

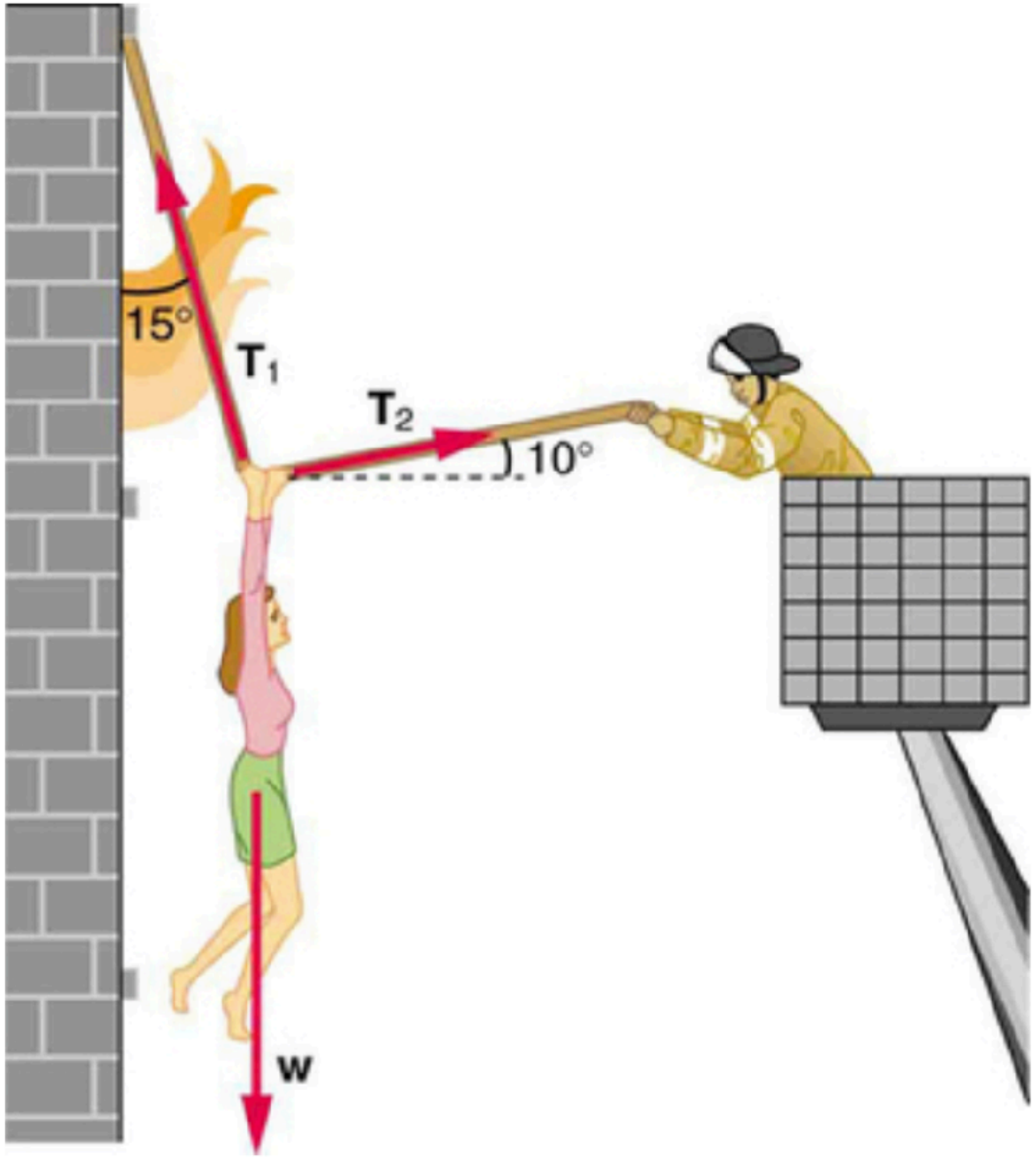
d) 1.00 m/s^2

A B C D E

Activity:
Worked Problems

WP 7.1

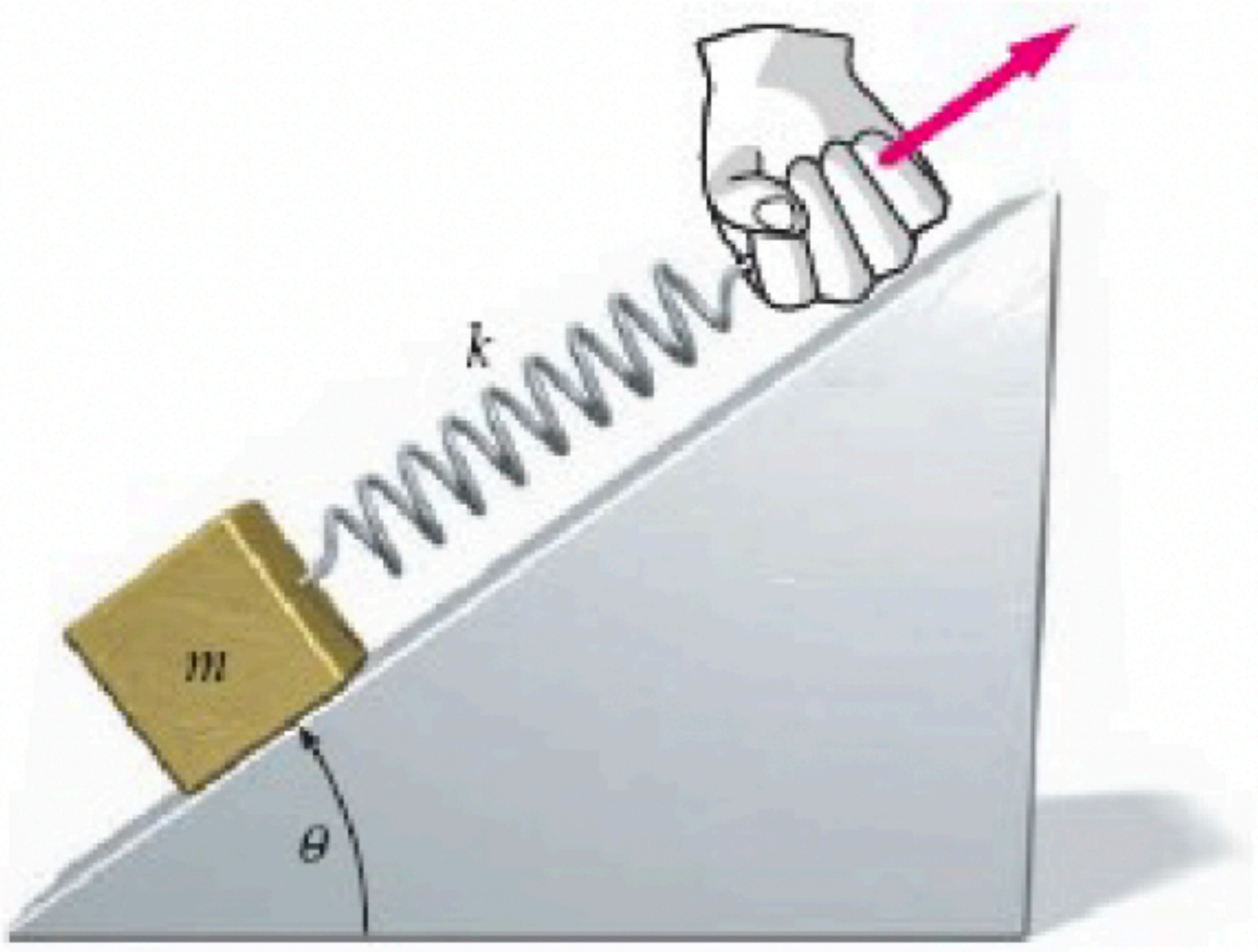
A 76.0-kg person is being pulled away from a burning building as shown in the figure. Calculate the tension in the two ropes if the person is momentarily motionless. Include a free-body diagram in your solution.



HW 6.8

HW6.8. Spring on Ramp

In the figure below m = 7 kg, $\theta = 30^\circ$, and k = 100 N/m. In this problem assume that the ramp never moves and that there is friction between the block and the ramp.



Part 1

If the coefficient of static friction between the block and the ramp is $\mu_s = 0.7$, what is the maximum amount that the spring can be stretched beyond its equilibrium length before the block begins to slide up the ramp?

$x =$ number (rtol=0.05, atol=1e-08) m

Part 2

Suppose now that the block is sliding up the ramp at a constant velocity. By what length is the spring stretched? Assume that the coefficient of kinetic friction is $\mu_k = 0.39$.

$x =$ number (rtol=0.05, atol=1e-08) m

HW 6.8

See you next class!

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