CHAPTER 4 Forces in One Dimension

Practice Problems

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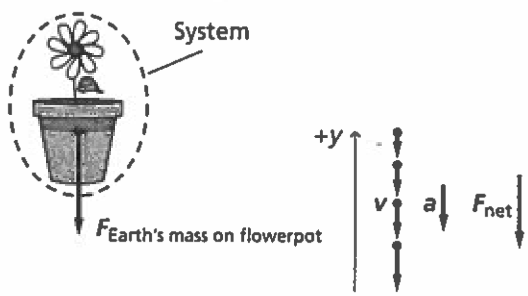
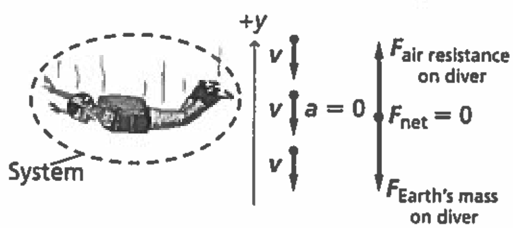
For each of the following situations, specify the system and draw a motion diagram and a free-body diagram. Label all forces with their agents, and indicate the direction of the acceleration and of the net force. Draw vectors of appropriate lengths.

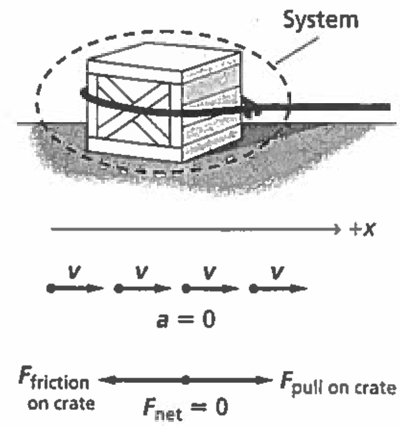
1. A flowerpot falls freely from a windowsill. (Ignore any forces due to air resistance.)



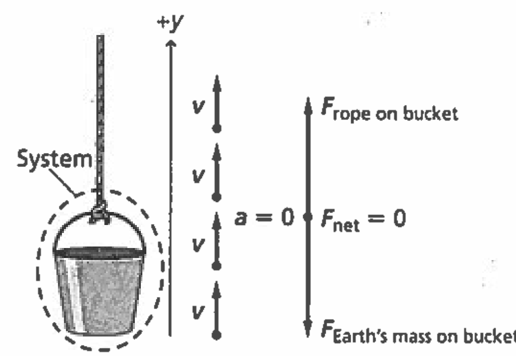
2. A sky diver falls downward through the air at constant velocity. (The air exerts an upward force on the person.)



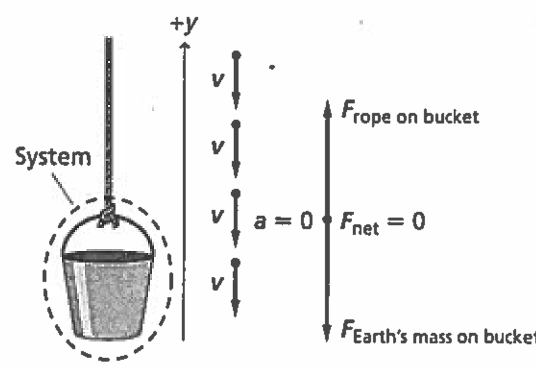
3. A cable pulls a crate at a constant speed across a horizontal surface. The surface provides a force that resists the crate's motion.



4. A rope lifts a bucket at a constant speed. (Ignore air resistance.)



5. A rope lowers a bucket at a constant speed. (Ignore air resistance.)



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6. Two horizontal forces, 225 N and 165 N, are exerted on a canoe. If these forces are applied in the same direction, find the net horizontal force on the canoe.

F_{net} = 225 N + 165 N = 3.90×10² N

in the direction of the two forces

7. If the same two forces as in the previous problem are exerted on the canoe in opposite directions, what is the net horizontal force on the canoe? Be sure to indicate the direction of the net force.

F_{net} = 225 N − 165 N = 6.0×10¹ N

in the direction of the larger force

8. Three confused sleigh dogs are trying to pull a sled across the Alaskan snow. Alutia pulls east with a force of 35 N, Seward also pulls east but with a force of 42 N, and big Kodiak pulls west with a force of 53 N. What is the net force on the sled?

Identify east as positive and the sled as the system.

$$F_{net} = F_{Alutia\ on\ sled} + F_{Seward\ on\ sled} - F_{Kodiak\ on\ sled}$$

= 35 N + 42 N − 53 N

= 24 N

F_{net} = 24 N east

Section Review

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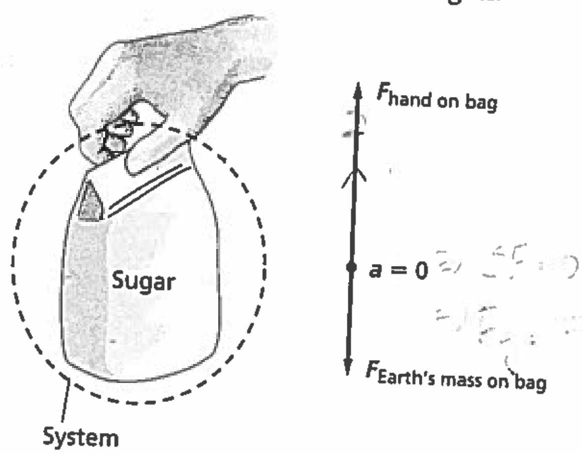
9. **Force** Identify each of the following as either **a, b,** or **c:** weight, mass, inertia, the push of a hand, thrust, resistance, air resistance, spring force, and acceleration.
   - **a.** a contact force
   - **b.** a field force
   - **c.** not a force

weight (b), mass (c), inertia (c), push of a hand (a), thrust (a), resistance (a), air resistance (a), spring force (a), acceleration (c)

10. **Inertia** Can you feel the inertia of a pencil? Of a book? If you can, describe how.

Yes, you can feel the inertia of either object by using your hand to give either object an acceleration; that is, try to change the objects velocity.

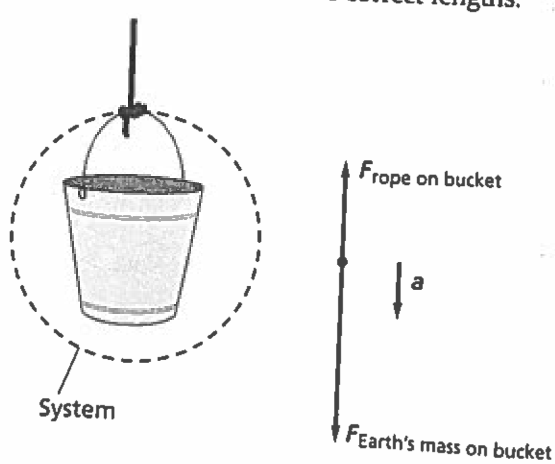
11. **Free-Body Diagram** Draw a free-body diagram of a bag of sugar being lifted by your hand at a constant speed. Specifically identify the system. Label all forces with their agents and make the arrows the correct lengths.



12. **Direction of Velocity** If you push a book in the forward direction, does this mean its velocity has to be forward?

No, it could be moving backward and you would be reducing that velocity.

13. **Free-Body Diagram** Draw a free-body diagram of a water bucket being lifted by a rope at a decreasing speed. Specifically identify the system. Label all forces with their agents and make the arrows the correct lengths.



14. Critical Thinking A force of 1 N is the only force exerted on a block, and the acceleration of the block is measured. When the same force is the only force exerted on a second block, the acceleration is three times as large. What can you conclude about the masses of the two blocks?

Because $m = F/a$ and the forces are the same, the mass of the second block is one-third the mass of the first block.

Practice Problems

4.2 Using Newton's Laws pages 96–101

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15. You place a watermelon on a spring scale at the supermarket. If the mass of the watermelon is 4.0 kg, what is the reading on the scale?

The scale reads the weight of the watermelon:

$F_g = mg = (4.0\text{ kg})(9.80\text{ m/s}^2) = 39\text{ N}$

16. Kamaria is learning how to ice-skate. She wants her mother to pull her along so that she has an acceleration of 0.80 m/s². If Kamaria's mass is 27.2 kg, with what force does her mother need to pull her? (Neglect any resistance between the ice and Kamaria's skates.)

$F_{net} = ma = (27.2\text{ kg})(0.80\text{ m/s}^2) = 22\text{ N}$

17. Taru and Reiko simultaneously grab a 0.75-kg piece of rope and begin tugging on it in opposite directions. If Taru pulls with a force of 16.0 N and the rope accelerates away from her at 1.25 m/s², with what force is Reiko pulling?

Identify Reiko's direction as positive and the rope as the system.

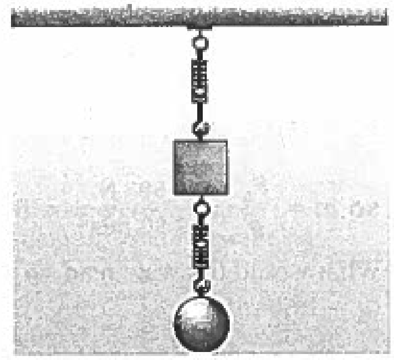
$F_{net} = F_{\text{Rieko on rope}} - F_{\text{Taru on rope}} = ma$

$F_{\text{Rieko on rope}} = ma + F_{\text{Taru on rope}}$

$= (0.75\text{ kg})(1.25\text{ m/s}^2) + 16.0\text{ N}$

$= 17\text{ N}$

18. In **Figure 4-8,** the block has a mass of 1.2 kg and the sphere has a mass of 3.0 kg. What are the readings on the two scales? (Neglect the masses of the scales.)



■ Figure 4-8

Bottom scale: Identify the sphere as the system and up as positive.

$F_{net} = F_{\text{scale on sphere}} - F_{\text{Earth's mass on sphere}} = ma = 0$

$F_{\text{scale on sphere}} = F_{\text{Earth's mass on sphere}}$

$= m_{\text{sphere}}g$

$= (3.0\text{ kg})(9.80\text{ m/s}^2)$

$= 29\text{ N}$

Top scale: Identify the block as the system and up as positive.

$F_{net} = F_{\text{top scale on block}} - F_{\text{bottom scale on block}} - F_{\text{Earth's mass on block}} = ma = 0$

$F_{\text{top scale on block}} = F_{\text{bottom scale on block}} + F_{\text{Earth's mass on block}}$

$= F_{\text{bottom scale on block}} + m_{\text{block}}g$

$= 29\text{ N} + (1.2\text{ kg})(9.80\text{ m/s}^2)$

$= 41\text{ N}$

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19. On Earth, a scale shows that you weigh 585 N.

a. What is your mass?

The scale reads 585 N. Since there is no acceleration, your weight equals the downward force of gravity:

$F_g = mg$

$$\text{so } m = \frac{F_g}{g} = \frac{585 \text{ N}}{9.80 \text{ m/s}^2} = 59.7 \text{ kg}$$

b. What would the scale read on the Moon ($g = 1.60 \text{ m/s}^2$)?

On the moon, *g* changes:

$$F_g = mg_{Moon}$$
$$= (59.7 \text{ kg})(1.60 \text{ m/s}^2)$$
$$= 95.5 \text{ N}$$

20. Use the results from Example Problem 2 to answer questions about a scale in an elevator on Earth. What force would be exerted by the scale on a person in the following situations?

a. The elevator moves at constant speed.

Constant speed, so $a = 0$ and $F_{net} = 0$.

$$F_{scale} = F_g$$
$$= mg = (75.0 \text{ kg})(9.80 \text{ m/s}^2)$$
$$= 735 \text{ N}$$

b. It slows at 2.00 m/s^2 while moving upward.

Slowing while moving upward, so

$a = -2.00 \text{ m/s}^2$

$$F_{scale} = F_{net} + F_g$$
$$= ma + mg$$
$$= m(a + g)$$
$$= (75.0 \text{ kg})(-2.00 \text{ m/s}^2 + 9.80 \text{ m/s}^2)$$
$$= 585 \text{ N}$$

c. It speeds up at 2.00 m/s^2 while moving downward.

Accelerating downward,

so $a = -2.00 \text{ m/s}^2$

$$F_{scale} = F_{net} + F_g$$
$$= ma + mg$$
$$= m(a + g)$$
$$= (75.0 \text{ kg})(-2.00 \text{ m/s}^2 + 9.80 \text{ m/s}^2)$$
$$= 585 \text{ N}$$

d. It moves downward at constant speed.

Constant speed, so
$a = 0$ and $F_{net} = 0$

$$F_{scale} = F_g = mg$$
$$= (75.0 \text{ kg})(9.80 \text{ m/s}^2)$$
$$= 735 \text{ N}$$

e. It slows to a stop at a constant magnitude of acceleration.

Constant acceleration = *a*, though the sign of *a* depends on the direction of the motion that is ending.

$$F_{scale} = F_{net} + F_g$$
$$= ma + mg$$
$$= (75.0 \text{ kg})(a) + (75.0 \text{ kg})(9.80 \text{ m/s}^2)$$
$$= (75.0 \text{ kg})(a) + 735 \text{ N}$$

24. **Motion of an Elevator** You are riding in an elevator holding a spring scale with a 1-kg mass suspended from it. You look at the scale and see that it reads 9.3 N. What, if anything, can you conclude about the elevator's motion at that time?

If the elevator is stationary or moving at a constant velocity, the scale should read 9.80 N. Because the scale reads a lighter weight, the elevator must be accelerating downward. To find the exact acceleration: identify up as positive and the 1-kg mass as the system.

$$F_{net} = F_{scale\ on\ 1\ kg} - F_{Earth's\ mass\ on\ 1\ kg} = ma$$

$$a = \frac{F_{scale\ on\ 1\ kg} - F_{Earth's\ mass\ on\ 1\ kg}}{m}$$

$$= \frac{9.3\ N - 9.80\ N}{1\ kg}$$

$$= -0.5\ m/s^2$$

$$= 0.5\ m/s^2 \text{ downward}$$

25. **Mass** Marcos is playing tug-of-war with his cat using a stuffed toy. At one instant during the game, Marcos pulls on the toy with a force of 22 N, the cat pulls in the opposite direction with a force of 19.5 N, and the toy experiences an acceleration of 6.25 m/s^2. What is the mass of the toy?

Identify the toy as the system and the direction toward Marcos as the positive direction.

$$F_{net} = F_{Marcos\ on\ toy} - F_{cat\ on\ toy} = ma$$

$$m = \frac{F_{Marcos\ on\ toy} - F_{cat\ on\ toy}}{a}$$

$$= \frac{22\ N - 19.5\ N}{6.25\ m/s^2}$$

$$= 0.40\ kg$$

26. **Acceleration** A sky diver falls at a constant speed in the spread-eagle position. After he opens his parachute, is the sky diver accelerating? If so, in which direction? Explain your answer using Newton's laws.

Yes, for a while the diver is accelerating upward because there is an additional upward force due to air resistance on the parachute. The upward acceleration causes the diver's downward velocity to decrease. Newton's second law says that a net force in a certain direction will result in an acceleration in that direction ($F_{net} = ma$).

27. **Critical Thinking** You have a job at a meat warehouse loading inventory onto trucks for shipment to grocery stores. Each truck has a weight limit of 10,000 N of cargo. You push each crate of meat along a low-resistance roller belt to a scale and weigh it before moving it onto the truck. However, right after you weigh a 1000-N crate, the scale breaks. Describe a way in which you could apply Newton's laws to figure out the approximate masses of the remaining crates.

Answers may vary. One possible answer is the following: You can neglect resistance if you do all your maneuvering on the roller belt. Because you know the weight of the 1000 N crate, you can use it as your standard. Pull on the 1000 N crate with a particular force for 1 s, estimate its velocity, and calculate the acceleration that your force gave to it. Next, pull on a crate of unknown mass with as close to the same force as you can for 1 s. Estimate the crate's velocity and calculate the acceleration your force gave to it. The force you pulled with on each crate will be the net force in each case.

$$F_{net\ 1000\text{-}N\ crate} = F_{net\ unknown\ crate}$$

$$(1000\ N)(a_{1000\text{-}N\ crate}) = (m_{unk})(a_{unk})$$

$$m_{unk} = \frac{(1000\ N)(a_{1000\text{-}N\ crate})}{a_{unk}}$$

Section Review

4.2 Using Newton's Laws pages 96–101

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21. **Lunar Gravity** Compare the force holding a 10.0-kg rock on Earth and on the Moon. The acceleration due to gravity on the Moon is 1.62 m/s².

To hold the rock on Earth:

$F_{net} = F_{Earth\ on\ rock} - F_{hold\ on\ rock} = 0$

$F_{hold\ on\ rock} = F_{Earth\ on\ rock} = mg_{Earth}$

$= (10.0\ kg)(9.80\ m/s^2)$

$= 98.0\ N$

To hold the rock on the Moon:

$F_{net} = F_{Moon\ on\ rock} - F_{hold\ on\ rock} = 0$

$F_{hold\ on\ rock} = F_{Moon\ on\ rock} = mg_{Moon}$

$= (10.0\ kg)(1.62\ m/s^2)$

$= 16.2\ N$

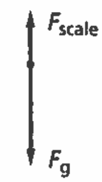
22. **Real and Apparent Weight** You take a ride in a fast elevator to the top of a tall building and ride back down while standing on a bathroom scale. During which parts of the ride will your apparent and real weights be the same? During which parts will your apparent weight be less than your real weight? More than your real weight? Sketch free-body diagrams to support your answers.

Apparent weight and real weight are the same when you are traveling either up or down at a constant velocity. Apparent weight is less than real weight when the elevator is slowing while rising or speeding up while descending. Apparent weight is greater when speeding up while rising or slowing while going down.

Constant Velocity

apparent weight = real weight

Slowing While Rising/ Speeding Up While Descending



apparent weight < real weight

Speeding Up While Rising/ Slowing While Descending

apparent weight > real weight

23. **Acceleration** Tecle, with a mass of 65.0 kg, is standing by the boards at the side of an ice-skating rink. He pushes off the boards with a force of 9.0 N. What is his resulting acceleration?

Identify Tecle as the system and the direction away from the boards as positive. The ice can be treated as a resistance-free surface.

$F_{net} = F_{boards\ on\ Tecle} = ma$

$a = \frac{F_{boards\ on\ Tecle}}{m}$

$= \frac{9.0\ N}{65.0\ kg}$

$= 0.14\ m/s^2$ **away from the boards**