4 Forces and Newton's Laws of Motion

4.1 Motion and Force

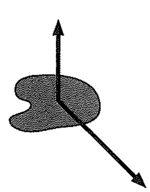
1. Using the particle model, draw the force a person exerts on a table when (a) pulling it to the right across a level floor with a force of magnitude F, (b) pulling it to the left across a level floor with force $2F$, and (c) *pushing* it to the right across a level floor with force F.

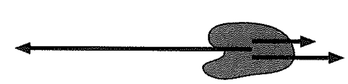
a. Table pulled right with force F

b. Table pulled left with force $2F$

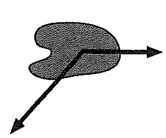
c. Table pushed right with force F

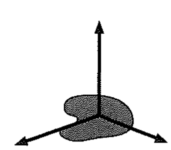
2. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{net}$.





3. Two or more forces are shown on the objects below. Draw and label the net force $\vec{F}_{net}$.





4.2 A Short Catalog of Forces

4.3 Identifying Forces

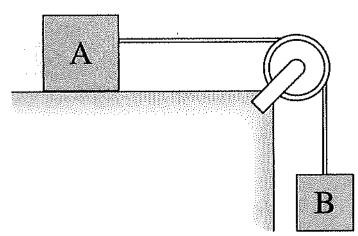
Exercises 4–8: Follow the six-step procedure of Tactics Box 4.2 to identify and name all the forces acting on the object.

4. An elevator suspended by a cable is descending at constant velocity.

5. A compressed spring is pushing a block across a rough horizontal table.

6. A brick is falling from the roof of a three-story building.

7. Blocks A and B are connected by a string passing over a pulley. Block B is falling and dragging block A across a frictionless table. Let block A be the object for analysis.



8. A rocket is launched at a 30° angle. Air resistance is not negligible.

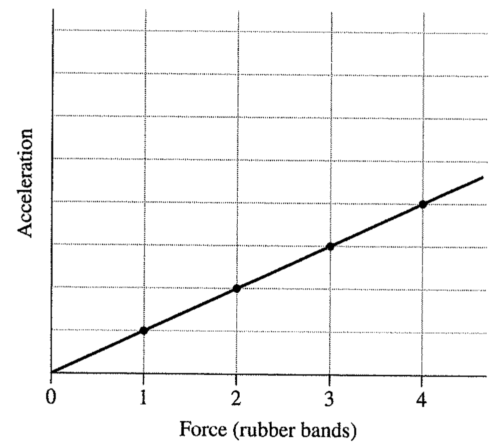
4.4 What Do Forces Do?

9. The figure shows an acceleration-versus-force graph for an object of mass m. Data have been plotted as individual points, and a line has been drawn through the points.

   Draw and label, directly on the figure, the acceleration-versus-force graphs for objects of mass

   a. $2m$ b. $0.5m$

   Use triangles ▲ to show four points for the object of mass $2m$, then draw a line through the points. Use squares ■ for the object of mass $0.5m$.



10. The quantity y is inversely proportional to x, and $y = 4$ when $x = 9$.

    a. Write an equation to represent this inverse relationship for all y and x.

    b. Find y if $x = 12$. ________ c. Find x if $y = 36$. ________

    d. Compare your equation in part a to the equation from your text relating a and m, $a = \frac{F}{m}$.

    Which quantity assumes the role of x? ________

    Which quantity assumes the role of y? ________

    What is the constant of proportionality relating a and m?

11. The quantity y is inversely proportional to x. For one value of x, $y = 12$.

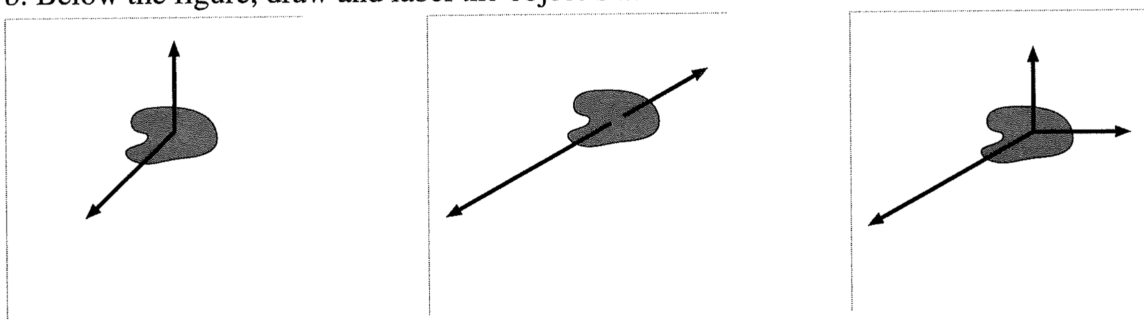
    a. What is the value of y if x is doubled? ________

    b. What is the value of y if the original value of x is halved? ________

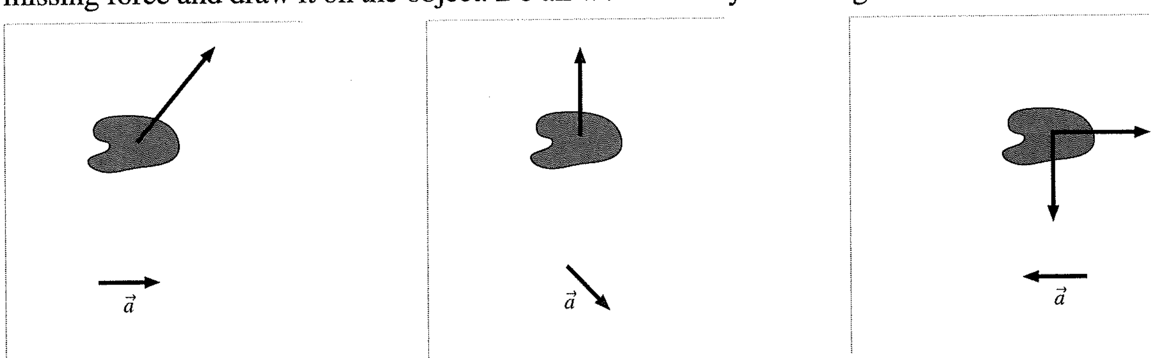
12. A steady force applied to a 2.0 kg mass causes it to accelerate at 4.0 m/s^2. The same force is then applied to a 4.0 kg mass. Use ratio reasoning to find the acceleration of the 4.0 kg mass.

4.5 Newton's Second Law

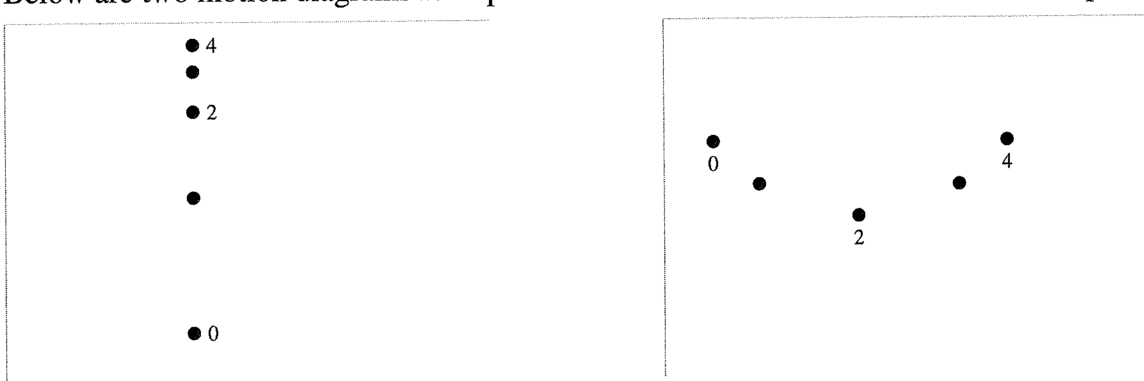
13. Forces are shown on three objects. For each:
    a. Draw and label the net force vector. Do this right on the figure.
    b. Below the figure, draw and label the object's acceleration vector.



14. In the figures below, one force is missing. Use the given direction of acceleration to determine the missing force and draw it on the object. Do all work directly on the figure.



15. Below are two motion diagrams for a particle. Draw and label the net force vector at point 2.



16. A constant force applied to an object causes the object to accelerate at 10 m/s^2. What will the acceleration of this object be if
    a. The force is doubled? ________ b. The mass is doubled? ________

    c. The force is doubled *and* the mass is doubled? ________

    d. The force is doubled *and* the mass is halved? ________

4.6 Free-Body Diagrams

Exercises 17–22:

- Draw a picture and identify the forces, following Tactics Box 4.2, then
- Draw a free-body diagram for the object, following each of the steps given in Tactics Box 4.3. Be sure to think carefully about the direction of $\vec{F}_{net}$.

Note: Draw individual force vectors with a **black** or **blue** pencil or pen. Draw the *net* force vector $\vec{F}_{net}$ with a **red** pencil or pen.

17. A heavy crate is being lowered straight down at a constant speed by a steel cable.

18. A boy is pushing a box across the floor at a steadily increasing speed. Let the box be the object for analysis.

19. A bicycle is speeding up down a hill. Friction is negligible, but air resistance is not.

20. You've slammed on your car brakes while going down a hill. The car is skidding to a halt.

21. You are going to toss a rock *straight up* into the air by placing it on the palm of your hand (you're not gripping it), then pushing your hand up very rapidly. You may want to toss an object into the air this way to help you think about the situation. The rock is the object of interest.

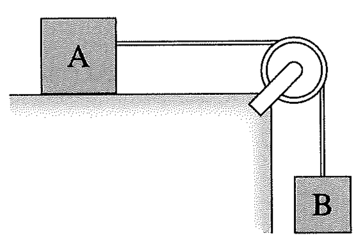
a. As you hold the rock at rest on your palm, before moving your hand.

b. As your hand is moving up but before the rock leaves your hand.

c. One-tenth of a second after the rock leaves your hand.

d. After the rock has reached its highest point and is now falling straight down.

22. Block B has just been released and is beginning to fall. Analyze block A.



4.7 Newton's Third Law

Exercises 23–25: Each of the following situations has two or more interacting objects. Draw a picture similar to Figure 4.30 in the textbook in which you

- Show the interacting objects, with a small gap separating them.
- Draw the force vectors of all action/reaction pairs.
- Label the force vectors, using a notation like $\vec{F}_{\text{A on B}}$ and $\vec{F}_{\text{B on A}}$.

23. A bat hits a ball. Draw your picture from the perspective of someone seeing the *end* of the bat at the moment it strikes the ball. The objects are the bat and the ball.

24. A boy pulls a wagon by its handle. Rolling friction is not negligible. The objects are the boy, the wagon, and the ground.

25. A crate is in the back of a truck as the truck accelerates forward. The crate does not slip. The objects are the truck, the crate, and the ground.

26. You find yourself in the middle of a frozen lake with a surface so slippery that you cannot walk. However, you happen to have several rocks in your pocket. The ice is extremely hard. It cannot be chipped, and the rocks slip on it just as much as your feet do. Can you think of a way to get to shore? Use pictures, forces, and Newton's laws to explain your reasoning.

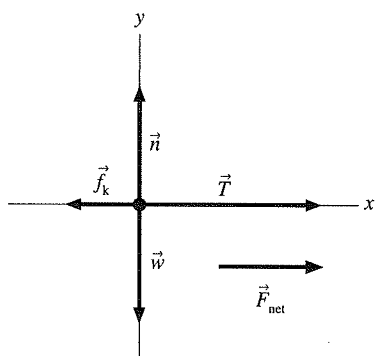
27. How do basketball players jump straight up into the air? Your explanation should include pictures showing forces on the player and forces on the ground.

You Write the Problem!

Exercises 28–32: You are given the free-body diagram of an object with one or more forces acting on it. For each of these:

a. Identify the direction of the object's acceleration $\vec{a}$. Draw and label the acceleration vector next to the free-body diagram. Or, if appropriate, write $\vec{a} = \vec{0}$.
b. Write a short description of a real object for which this is the correct free-body diagram. Use the worked examples in the textbook as models of what a description should be like.

28.



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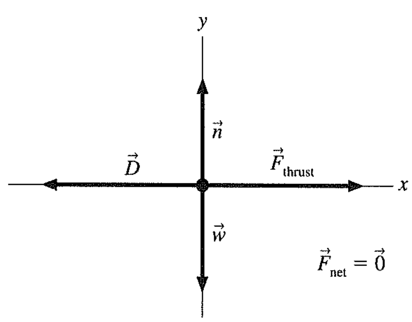

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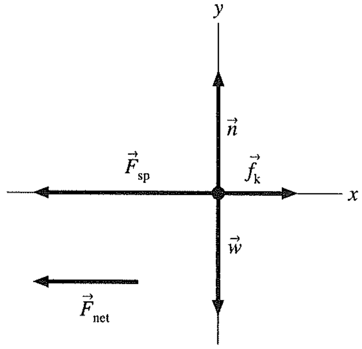

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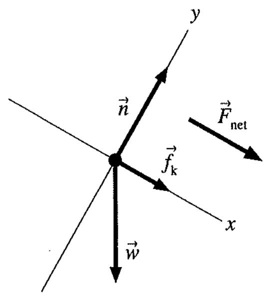

32.