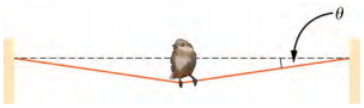
18.E: Newton's Laws of Motion (Exercises)

Conceptual Questions

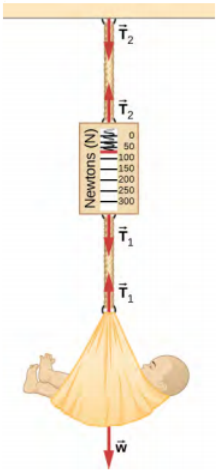
1. A table is placed on a rug. Then a book is placed on the table. What does the floor exert a normal force on?
2. A particle is moving to the right. (a) Can the force on it to be acting to the left? If yes, what would happen? (b) Can that force be acting downward? If yes, why?
3. In completing the solution for a problem involving forces, what do we do after constructing the free-body diagram? That is, what do we apply?
4. If a book is located on a table, how many forces should be shown in a free-body diagram of the book? Describe them.
5. If the book in the previous question is in free fall, how many forces should be shown in a free-body diagram of the book? Describe them.

Problems

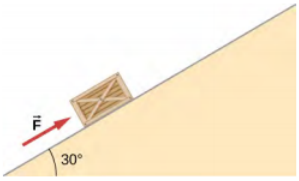
7.
8. A team of nine members on a tall building tug on a string attached to a large boulder on an icy surface. The boulder has a mass of 200 kg and is tugged with a force of 2350 N. (a) What is magnitude of the acceleration? (b) What force would be required to produce a constant velocity?
9. What force does a trampoline have to apply to Jennifer, a 45.0-kg gymnast, to accelerate her straight up at 7.50 m/s^2? The answer is independent of the velocity of the gymnast—she can be moving up or down or can be instantly stationary.
10. (a) Calculate the tension in a vertical strand of spider web if a spider of mass 2.00 x 10^{-5} kg hangs motionless on it. (b) Calculate the tension in a horizontal strand of spider web if the same spider sits motionless in the middle of it much like the tightrope walker in Figure 5.26. The strand sags at an angle of 12° below the horizontal. Compare this with the tension in the vertical strand (find their ratio).
11. Suppose Kevin, a 60.0-kg gymnast, climbs a rope. (a) What is the tension in the rope if he climbs at a constant speed? (b) What is the tension in the rope if he accelerates upward at a rate of 1.50 m/s^2?
12. Show that, as explained in the text, a force $F_\perp$ exerted on a flexible medium at its center and perpendicular to its length (such as on the tightrope wire in Figure 5.26) gives rise to a tension of magnitude $T = \frac{F_\perp}{2 \sin \theta}$.
13. Consider Figure 5.28. The driver attempts to get the car out of the mud by exerting a perpendicular force of 610.0 N, and the distance she pushes in the middle of the rope is 1.00 m while she stands 6.00 m away from the car on the left and 6.00 m away from the tree on the right. What is the tension T in the rope, and how do you find the answer?
14. 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) θ = 5° and (c) θ = 0.5°. Assume that each half of the line is straight.



64. One end of a 30-m rope is tied to a tree; the other end is tied to a car stuck in the mud. The motorist pulls sideways on the midpoint of the rope, displacing it a distance of 2 m. If he exerts a force of 80 N under these conditions, determine the force exerted on the car.
65. Consider the baby being weighed in the following figure. (a) What is the mass of the infant and basket if a scale reading of 55 N is observed? (b) What is tension T_1 in the cord attaching the baby to the scale? (c) What is tension T_2 in the cord attaching the scale to the ceiling, if the scale has a mass of 0.500 kg? (d) Sketch the situation, indicating the system of interest used to solve each part. The masses of the cords are negligible.



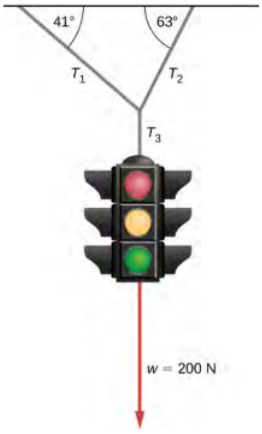
66. What force must be applied to a 100.0-kg crate on a frictionless plane inclined at 30° to cause an acceleration of 2.0 m/s^2 up the plane?



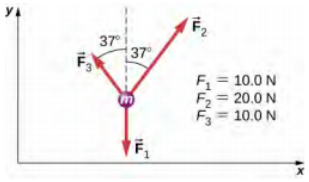
67. A 2.0-kg block is on a perfectly smooth ramp that makes an angle of 30° with the horizontal. (a) What is the block's acceleration down the ramp and the force of the ramp on the block? (b) What force applied upward along and parallel to the ramp would allow the block to move with constant velocity?

68. A runner pushes against the track, as shown. (a) Provide a free-body diagram showing all the forces on the runner. (**Hint**: Place all forces at the center of his body, and include his weight.) (b) Give a revised diagram showing the xy-component form.

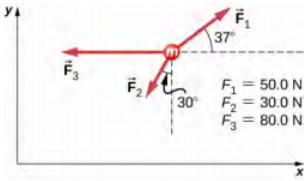
71. The traffic light hangs from the cables as shown. Draw a free-body diagram on a coordinate plane for this situation.



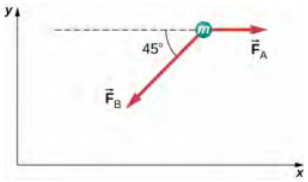
72. Two forces of 25 and 45 N act on an object. Their directions differ by 70°. The resulting acceleration has magnitude of 10.0 m/s^2. What is the mass of the body?
73. A force of 1600 N acts parallel to a ramp to push a 300-kg piano into a moving van. The ramp is inclined at 20°. (a) What is the acceleration of the piano up the ramp? (b) What is the velocity of the piano when it reaches the top if the ramp is 4.0 m long and the piano starts from rest?
74. Draw a free-body diagram of a diver who has entered the water, moved downward, and is acted on by an upward force due to the water which balances the weight (that is, the diver is suspended).
75. For a swimmer who has just jumped off a diving board, assume air resistance is negligible. The swimmer has a mass of 80.0 kg and jumps off a board 10.0 m above the water. Three seconds after entering the water, her downward motion is stopped. What average upward force did the water exert on her?
76. (a) Find an equation to determine the magnitude of the net force required to stop a car of mass m, given that the initial speed of the car is v_0 and the stopping distance is x. (b) Find the magnitude of the net force if the mass of the car is 1050 kg, the initial speed is 40.0 km/h, and the stopping distance is 25.0 m.
77. A sailboat has a mass of 1.50 x 10^3 kg and is acted on by a force of 2.00 x 10^3 N toward the east, while the wind acts behind the sails with a force of 3.00 x 10^3 N in a direction 45° north of east. Find the magnitude and direction of the resulting acceleration.
78. Find the acceleration of the body of mass 10.0 kg shown below.



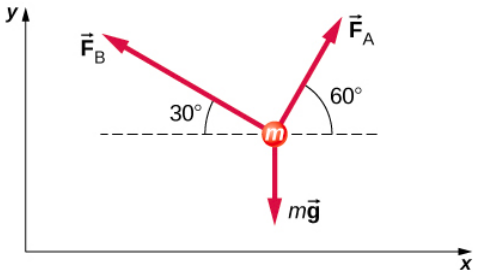
80. A body of mass 2.0 kg is moving along the x-axis with a speed of 3.0 m/s at the instant represented below. (a) What is the acceleration of the body? (b) What is the body's velocity 10.0 s later? (c) What is its displacement after 10.0 s?



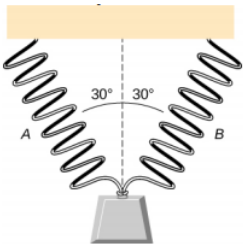
81. Force $\vec{F}_B$ has twice the magnitude of force $\vec{F}_A$. Find the direction in which the particle accelerates in this figure.



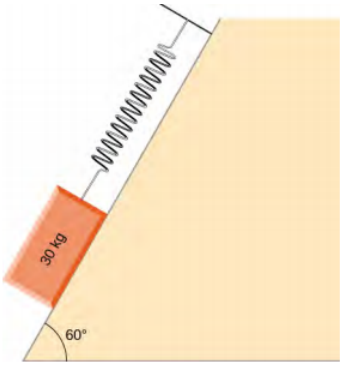
82. Shown below is a body of mass 1.0 kg under the influence of the forces $\vec{F}_A$, $\vec{F}_B$, and m$\vec{g}$. If the body accelerates to the left at 20 m/s^2, what are $\vec{F}_A$ and $\vec{F}_B$?



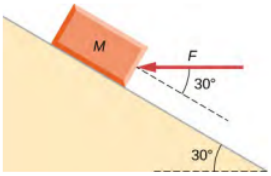
83. A force acts on a car of mass m so that the speed v of the car increases with position x as v = kx^2, where k is constant and all quantities are in SI units. Find the force acting on the car as a function of position.
84. A 7.0-N force parallel to an incline is applied to a 1.0-kg crate. The ramp is tilted at 20° and is frictionless. (a) What is the acceleration of the crate? (b) If all other conditions are the same but the ramp has a friction force of 1.9 N, what is the acceleration?
85. Two boxes, A and B, are at rest. Box A is on level ground, while box B rests on an inclined plane tilted at angle θ with the horizontal. (a) Write expressions for the normal force acting on each block. (b) Compare the two forces; that is, tell which one is larger or whether they are equal in magnitude. (c) If the angle of incline is 10°, which force is greater?
86. A mass of 250.0 g is suspended from a spring hanging vertically. The spring stretches 6.00 cm. How much will the spring stretch if the suspended mass is 530.0 g?
87. As shown below, two identical springs, each with the spring constant 20 N/m, support a 15.0-N weight. (a) What is the tension in spring A? (b) What is the amount of stretch of spring A from the rest position?



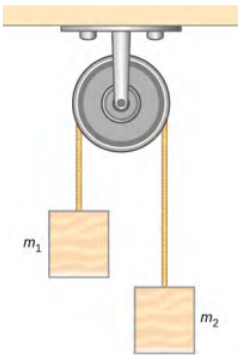
88. Shown below is a 30.0-kg block resting on a frictionless ramp inclined at 60° to the horizontal. The block is held by a spring that is stretched 5.0 cm. What is the force constant of the spring?



89. In building a house, carpenters use nails from a large box. The box is suspended from a spring twice during the day to measure the usage of nails. At the beginning of the day, the spring stretches 50 cm. At the end of the day, the spring stretches 30 cm. What fraction or percentage of the nails have been used?
90. A force is applied to a block to move it up a 30° incline. The incline is frictionless. If F = 65.0 N and M = 5.00 kg, what is the magnitude of the acceleration of the block?

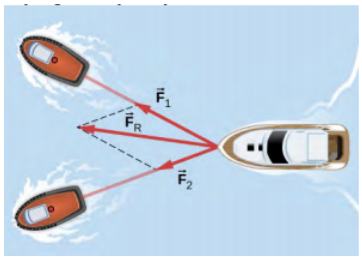


91. Two forces are applied to a 5.0-kg object, and it accelerates at a rate of 2.0 m/s^2 in the positive y-direction. If one of the forces acts in the positive x-direction with magnitude 12.0 N, find the magnitude of the other force.
92. The block on the right shown below has more mass than the block on the left ($m_2 > m_1$). Draw free-body diagrams for each block.



Challenge Problems

93. If two tugboats pull on a disabled vessel, as shown here in an overhead view, the disabled vessel will be pulled along the direction indicated by the result of the exerted forces. (a) Draw a free-body diagram for the vessel. Assume no friction or drag forces affect the vessel. (b) Did you include all forces in the overhead view in your free-body diagram? Why or why not?



94. A 10.0-kg object is initially moving east at 15.0 m/s. Then a force acts on it for 2.00 s, after which it moves northwest, also at 15.0 m/s. What are the magnitude and direction of the average force that acted on the object over the 2.00-s interval?
95. On June 25, 1983, shot-putter Udo Beyer of East Germany threw the 7.26-kg shot 22.22 m, which at that time was a world record. (a) If the shot was released at a height of 2.20 m with a projection angle of 45.0°, what was its initial velocity? (b) If while in Beyer's hand the shot was accelerated uniformly over a distance of 1.20 m, what was the net force on it?
96. A body of mass m moves in a horizontal direction such that at time t its position is given by $x(t) = at^4 + bt^3 + ct$, where a, b, and c are constants. (a) What is the acceleration of the body? (b) What is the time-dependent force acting on the body?
97. A body of mass m has initial velocity v_0 in the positive x-direction. It is acted on by a constant force F for time t until the velocity becomes zero; the force continues to act on the body until its velocity becomes $-v_0$ in the same amount of time.

Write an expression for the total distance the body travels in terms of the variables indicated.

98. The velocities of a 3.0-kg object at t = 6.0 s and t = 8.0 s are (3.0 $\hat{i}$ − 6.0 $\hat{j}$ + 4.0 $\hat{k}$) m/s and (−2.0 $\hat{i}$ + 4.0 $\hat{k}$) m/s, respectively. If the object is moving at constant acceleration, what is the force acting on it?
99. A 120-kg astronaut is riding in a rocket sled that is sliding along an inclined plane. The sled has a horizontal component of acceleration of 5.0 m/s^2 and a downward component of 3.8 m/s^2. Calculate the magnitude of the force on the rider by the sled. (**Hint**: Remember that gravitational acceleration must be considered.)
100. Two forces are acting on a 5.0-kg object that moves with acceleration 2.0 m/s^2 in the positive y-direction. If one of the forces acts in the positive x-direction and has magnitude of 12 N, what is the magnitude of the other force?
101. Suppose that you are viewing a soccer game from a helicopter above the playing field. Two soccer players simultaneously kick a stationary soccer ball on the flat field; the soccer ball has mass 0.420 kg. The first player kicks with force 162 N at 9.0° north of west. At the same instant, the second player kicks with force 215 N at 15° east of south. Find the acceleration of the ball in $\hat{i}$ and $\hat{j}$ form.
102. A 10.0-kg mass hangs from a spring that has the spring constant 535 N/m. Find the position of the end of the spring away from its rest position. (Use g = 9.80 m/s^2.)
103. A 0.0502-kg pair of fuzzy dice is attached to the rearview mirror of a car by a short string. The car accelerates at constant rate, and the dice hang at an angle of 3.20° from the vertical because of the car's acceleration. What is the magnitude of the acceleration of the car?
104. In a particle accelerator, a proton has mass 1.67 x 10^{-27} kg and an initial speed of 2.00 x 10^5 m/s. It moves in a straight line, and its speed increases to 9.00 x 10^5 m/s in a distance of 10.0 cm. Assume that the acceleration is constant. Find the magnitude of the force exerted on the proton.

106. A drone is being directed across a frictionless ice-covered lake. The mass of the drone is 1.50 kg, and its velocity is 3.00 $\hat{i}$ m/s. After 10.0 s, the velocity is 9.00 $\hat{i}$ + 4.00 $\hat{j}$ m/s. If a constant force in the horizontal direction is causing this change in motion, find (a) the components of the force and (b) the magnitude of the force.

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