Chapter 4: Dynamics: Force and Newton’s Laws of Motion

# 4.3 Newton’s Second Law of Motion: Concept of a System

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| 1. | *A 63.0-kg sprinter starts a race with an acceleration of* *. What is the net external force on him?* |
| Solution |  |
| 2. | *If the sprinter from the previous problem accelerates at that rate for 20 m, and then maintains that velocity for the remainder of the 100-m dash, what will be his time for the race?* |
| Solution | Running from rest, runner attains a velocity of    or  at end of acceleration.  Find the time for this first part using , or . For the second part, with no acceleration, , or .  (a record!) |
| 3. | *A cleaner pushes a 4.50-kg laundry cart in such a way that the net external force on it is 60.0 N. Calculate the magnitude its acceleration.* |
| Solution | of the cart. |
| 4. | *Since astronauts in orbit are apparently weightless, a clever method of measuring their masses is needed to monitor their mass gains or losses to adjust diets. One way to do this is to exert a known force on an astronaut and measure the acceleration produced. Suppose a net external force of 50.0 N is exerted and the astronaut’s acceleration is measured to be* *. (a) Calculate her mass. (b) By exerting a force on the astronaut, the vehicle in which they orbit experiences an equal and opposite force. Discuss how this would affect the measurement of the astronaut’s acceleration. Propose a method in which recoil of the vehicle is avoided.* |
| Solution | (a)  (b)  If the force could be exerted on the astronaut by another source (other than the spaceship), then the spaceship would not experience a recoil. |
| 5. | *In Figure 4.7, the net external force on the 24-kg mower is stated to be 51 N. If the force of friction opposing the motion is 24 N, what force  (in newtons) is the person exerting on the mower? Suppose the mower is moving at 1.5 m/s when the force  is removed. How far will the mower go before stopping?* |
| Solution |  |
| 6. | *The same rocket sled drawn in Figure 4.31 is decelerated at a rate of* *. What force is necessary to produce this deceleration? Assume that the rockets are off. The mass of the system is 2100 kg.* |
| Solution |  |
| 7. | *(a) If the rocket sled shown in Figure 4.32 starts with only one rocket burning, what is the magnitude of its acceleration? Assume that the mass of the system is 2100 kg, the thrust T is 2.6 x 10 4 N, and the force of friction opposing the motion is known to be 650 N. (b) Why is the acceleration not one-fourth of what it is with all rockets burning?* |
| Solution | (a) Use the thrust given for the rocket sled in Figure 4.8, . With only one rocket burning, or  (b) The acceleration is not one-fourth of what it was with all rockets burning because the frictional force is still as large as it was with all rockets burning. |
| 8. | *What is the deceleration of the rocket sled if it comes to rest in 1.1 s from a speed of 1000 km/h? (Such deceleration caused one test subject to black out and have temporary blindness.)* |
| Solution |  |
| 9. | *Suppose two children push horizontally, but in exactly opposite directions, on a third child in a wagon. The first child exerts a force of 75.0 N, the second a force of 90.0 N, friction is 12.0 N, and the mass of the third child plus wagon is 23.0 kg. (a) What is the system of interest if the acceleration of the child in the wagon is to be calculated? (b) Draw a free-body diagram, including all forces acting on the system. (c) Calculate the acceleration. (d) What would the acceleration be if friction were 15.0 N?* |
| Solution | (a) The system is the child in the wagon plus the wagon.  (b)  (c)  so that    (d) |
| 10. | *A powerful motorcycle can produce an acceleration of*  *while traveling at 90.0 km/h. At that speed the forces resisting motion, including friction and air resistance, total 400 N. (Air resistance is analogous to air friction. It always opposes the motion of an object.) What is the magnitude of the force that the motorcycle exerts backward on the ground to produce its acceleration if the mass of the motorcycle with rider is 245 kg?* |
| Solution |  |
| 11. | *The rocket sled shown in Figure 4.33 accelerates at a rate of* *. Its passenger has a mass of 75.0 kg. (a) Calculate the horizontal component of the force the seat exerts against his body. Compare this with his weight by using a ratio. (b) Calculate the direction and magnitude of the total force the seat exerts against his body.* |
| Solution | (a)  (b) |
| 12. | *Repeat the previous problem for the situation in which the rocket sled decelerates at a rate of . In this problem, the forces are exerted by the seat and restraining belts.* |
| Solution | (a)  (b) |
| 13. | *The weight of an astronaut plus his space suit on the Moon is only 250 N. How much do they weigh on Earth? What is the mass on the Moon? On Earth?* |
| Solution | Mass does not change, so the astronaut's mass on both Earth and the Moon will be 150 kg. |
| 14. | *Suppose the mass of a fully loaded module in which astronauts take off from the Moon is 10,000 kg. The thrust of its engines is 30,000 N. (a) Calculate the magnitude of its acceleration in a vertical takeoff from the Moon. (b) Could it lift off from Earth? If not, why not? If it could, calculate the magnitude of its acceleration.* |
| Solution | (a)  (b) The module cannot take off from the earth, since  of the earth. |

# 4.4 Newton’s Third Law of Motion: Symmetry in Forces

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| 15. | *What net external force is exerted on a 1100-kg artillery shell fired from a battleship if the shell is accelerated at* *? What is the magnitude of the force exerted on the ship by the artillery shell?* |
| Solution | opposite to shell’s direction of motion, by Newton’s 3rd law. |
| 16. | *A brave but inadequate rugby player is being pushed backward by an opposing player who is exerting a force of 800 N on him. The mass of the losing player plus equipment is 90.0 kg, and he is accelerating at*  *backward. (a) What is the force of friction between the losing player’s feet and the grass? (b) What force does the winning player exert on the ground to move forward if his mass plus equipment is 110 kg? (c) Draw a sketch of the situation showing the system of interest used to solve each part. For this situation, draw a free-body diagram and write the net force equation.* |
| Solution | (a)  (b)  (c) |

# 4.5 Normal, Tension, and Other Examples of Forces

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| 17. | *Two teams of nine members each engage in a tug of war. Each of the first team’s members has an average mass of 68 kg and exerts an average force of 1350 N horizontally. Each of the second team’s members has an average mass of 73 kg and exerts an average force of 1365 N horizontally. (a) What is the magnitude of the acceleration of the two teams? (b) What is the tension in the section of rope between the teams?* |
| Solution | (a)    Thus, the heavy team wins. Note that the difference  limits the answer to two significant figures.  (b ) |
| 18. | *What force does a trampoline have to apply to a 45.0-kg gymnast to accelerate her straight up at ? Note that the answer is independent of the velocity of the gymnast—she can be moving either up or down, or be stationary.* |
| Solution |  |
| 19. | *(a) Calculate the tension in a vertical strand of spider web if a spider of mass*  *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 4.17. The strand sags at an angle of*  *below the horizontal. Compare this with the tension in the vertical strand (find their ratio).* |
| Solution | (a)  (b) |
| 20. | *Suppose 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 ?* |
| Solution | (a)  (b) |
| 21. | *Show that, as stated in the text, a force  exerted on a flexible medium at its center and perpendicular to its length (such as on the tightrope wire in Figure 4.17) gives rise to a tension of magnitude .* |
| Solution |  |
| 22. | *Consider the baby being weighed in Figure 4.34. (a) What is the mass of the child and basket if a scale reading of 55 N is observed? (b) What is the tension in the cord attaching the baby to the scale? (c) What is the tension  in the cord attaching the scale to the ceiling, if the scale has a mass of 0.500 kg? (d) Draw a sketch of the situation indicating the system of interest used to solve each part. The masses of the cords are negligible.* |
| Solution | (a)  (b)  (c)  (d) |

# 4.6 Problem-Solving Strategies

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| 23. | *A*  *rocket is accelerating straight up. Its engines produce  of thrust, and air resistance is . What is the rocket’s acceleration? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion.* |
| Solution | fbd  Using the free body diagram: so that |
| 24. | *The wheels of a midsize car exert a force of 2100 N backward on the road to accelerate the car in the forward direction. If the force of friction including air resistance is 250 N and the acceleration of the car is , what is the mass of the car plus its occupants? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion. For this situation, draw a free-body diagram and write the net force equation.* |
| Solution | Using the free body diagram: so that |
| 25. | *Calculate the force a 70.0-kg high jumper must exert on the ground to produce an upward acceleration 4.00 times the acceleration due to gravity. Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion.* |
| Solution | Step 1. Use Newton’s Laws of Motion.    Step 2. Given :  Find .  Step 3.  so that    The force exerted by the high-jumper is actually down on the ground, but  is up from the ground to help him jump.  Step 4. This result is reasonable, since it is quite possible for a person to exert a force of the magnitude of . |
| 26. | *When landing after a spectacular somersault, a 40.0-kg gymnast decelerates by pushing straight down on the mat. Calculate the force she must exert if her deceleration is 7.00 times the acceleration due to gravity. Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion.* |
| Solution | Using the free body diagram:  Solving for the force gives  and substituting in the values gives |
| 27. | *A freight train consists of two*  *engines and 45 cars with average masses of* *. (a) What force must each engine exert backward on the track to accelerate the train at a rate of  if the force of friction is , assuming the engines exert identical forces? This is not a large frictional force for such a massive system. Rolling friction for trains is small, and consequently trains are very energy-efficient transportation systems. (b) What is the force in the coupling between the 37th and 38th cars (this is the force each exerts on the other), assuming all cars have the same mass and that friction is evenly distributed among all of the cars and engines?* |
| Solution | (a)  (b) The 37th car has 8 cars (45-38) behind it and since friction is evenly distributed:  Substituting gives: |
| 28. | *Commercial airplanes are sometimes pushed out of the passenger loading area by a tractor. (a) An 1800-kg tractor exerts a force of  backward on the pavement, and the system experiences forces resisting motion that total 2400 N. If the acceleration is , what is the mass of the airplane? (b) Calculate the force exerted by the tractor on the airplane, assuming 2200 N of the friction is experienced by the airplane. (c) Draw two sketches showing the systems of interest used to solve each part, including the free-body diagrams for each.* |
| Solution | (a)  (b)  (c) |
| 29. | *A 1100-kg car pulls a boat on a trailer. (a) What total 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 ? The mass of the boat plus trailer is 700 kg. (b) What is the force in the hitch between the car and the trailer if 80% of the resisting forces are experienced by the boat and trailer?* |
| Solution | (a)  (b) |
| 30. | *(a) Find the magnitudes of the forces  and that add to give the total force  shown in Figure 4.35. This may be done either graphically or by using trigonometry. (b) Show graphically that the same total force is obtained independent of the order of addition of  and . (c) Find the direction and magnitude of some other pair of vectors that add to give. Draw these to scale on the same drawing used in part (b) or* *a similar picture.* |
| Solution | (a) Since  is the -component of the total force:  .  And  is the -component of the total force:  .  (b)  (c) For example, use vectors as shown in the figure.    is at an angle of  from the horizontal, with a magnitude of  is at an angle of from the horizontal, with a magnitude of |
| 31. | *Two children pull a third child on a snow saucer sled exerting forces  and  as shown from above in Figure 4.36. Find the acceleration of the 49.00-kg sled and child system. Note that the direction of the frictional force is unspecified; it will be in the opposite direction of the sum of  and .* |
| Solution | Each force vector needs to be broken into its components:    Because there is a frictional force of 7.5N,      The child-sled combo are accelerating at |
| 32. | *Suppose your car was mired deeply in the mud and you wanted to use the method illustrated in Figure 4.37 to pull it out. (a) What force would you have to exert perpendicular to the center of the rope to produce a force of 12,000 N on the car if the angle is 2.00°? In this part, explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion. (b) Real ropes stretch under such forces. What force would be exerted on the car if the angle increases to 7.00° and you still apply the force found in part (a) to its center?* |
| Solution | (a) Use Figure 4.37 as the free body diagram.    (b) |
| 33. | *What force is exerted on the tooth in Figure 4.38 if the tension in the wire is 25.0 N? Note that the force applied to the tooth is smaller than the tension in the wire, but this is necessitated by practical considerations of how force can be applied in the mouth. Explicitly show how you follow steps in the Problem-Solving Strategy for Newton’s laws of motion.* |
| Solution | Step 1: Use Newton’s laws since we are looking for forces.  Step 2: Draw a force diagram:    Step 3: Given , find Using Newton’s laws gives  so that the applied force is due to the -components of the two tensions:  The -components of the tension cancel.  Step 4: This seems reasonable, since the applied tensions should be greater than the force applied to the tooth. |
| 34. | *Figure 4.39 shows Superhero and Trusty Sidekick hanging motionless from a rope. Superhero’s mass is 90.0 kg, while Trusty Sidekick’s is 55.0 kg, and the mass of the rope is negligible. (a) Draw a free-body diagram of the situation showing all forces acting on Superhero, Trusty Sidekick, and the rope. (b) Find the tension in the rope above Superhero. (c) Find the tension in the rope between Superhero and Trusty Sidekick. Indicate on your free-body diagram the system of interest used to solve each part.* |
| Solution | (a)  (b) Using the upper circle of the diagram, , so that .  Using the lower circle of the diagram, , giving .  Next, write the weights in terms of masses: .  Solving for the tension in the upper rope gives:    Plugging in the numbers gives:  Using the lower circle of the diagram, net , so that . Again, write the weight in terms of mass:  Solving for the tension in the lower rope gives: |
| 35. | *A nurse pushes a cart by exerting a force on the handle at a downward angle  below the horizontal. The loaded cart has a mass of 28.0 kg, and the force of friction is 60.0 N. (a) Draw a free-body diagram for the system of interest. (b) What force must the nurse exert to move at a constant velocity?* |
| Solution | (a) G:\Team Drives\CONNEX180067 - College Maintenance 2018-2019\03_Art_Corrections\01_College_Physics\CP_12_012019\02_Initial_Art_fr_Prod\JPEG\Figure_04_06_35.jpg  (b) To move at a constant velocity, . Since , . |
| 38. | ***Unreasonable Results*** *(a) Repeat Exercise 4.29, but assume an acceleration of  is produced. (b) What is unreasonable about the result? (c) Which premise is unreasonable, and why is it unreasonable?* |
| Solution | (a)  (b) It is unreasonable that the force of friction be in the direction of motion.  (c) The unreasonable premise is that an acceleration of  could be produced. |
| 39. | ***Unreasonable Results*** *(a) What is the initial acceleration of a rocket that has a mass of*  *at takeoff, the engines of which produce a thrust of ? Do not neglect gravity. (b) What is unreasonable about the result? (This result has been unintentionally achieved by several real rockets.) (c) Which premise is unreasonable, or which premises are inconsistent? (You may find it useful to compare this problem to the rocket problem earlier in this section.)* |
| Solution | (a)  (b) There is not enough thrust to take off .  (c) The thrust is not large enough for the given rocket mass to leave the ground. |

# 4.7 Further Applications of Newton’s Laws of Motion

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| 40. | *A flea jumps by exerting a force of  straight down on the ground. A breeze blowing on the flea parallel to the ground exerts a force of  on the flea. Find the direction and magnitude of the acceleration of the flea if its mass is* *. Do not neglect the gravitational force.* |
| Solution |  |
| 41. | *Two muscles in the back of the leg pull upward on the Achilles tendon, as shown in Figure 4.40. (These muscles are called the medial and lateral heads of the gastrocnemius muscle.) Find the magnitude and direction of the total force on the Achilles tendon. What type of movement could be caused by this force?* |
| Solution | Force on Achilles tendon . Force used to raise heel. |
| 42. | *A 76.0-kg person is being pulled away from a burning building as shown in Figure 4.41. Calculate the tension in the two ropes if the person is momentarily motionless. Include a free-body diagram in your solution.* |
| Solution |  |
| 43. | ***Integrated Concepts*** *A 35.0-kg dolphin decelerates from 12.0 to 7.50 m/s in 2.30 s to join another dolphin in play. What average force was exerted to slow him if he was moving horizontally? (The gravitational force is balanced by the buoyant force of the water.)* |
| Solution |  |
| 44. | ***Integrated Concepts*** *When starting a foot race, a 70.0-kg sprinter exerts an average force of 650 N backward on the ground for 0.800 s. (a) What is his final speed? (b) How far does he travel?* |
| Solution | (a)  (b) |
| 45. | ***Integrated Concepts*** *A large rocket has a mass of*  *at takeoff, and its engines produce a thrust of . (a) Find its initial acceleration if it takes off vertically. (b) How long does it take to reach a velocity of 120 km/h straight up, assuming constant mass and thrust? (c) In reality, the mass of a rocket decreases significantly as its fuel is consumed. Describe qualitatively how this affects the acceleration and time for this motion.* |
| Solution | (a)  (b)  (c) As the mass of the rocket decreases, the acceleration increases for the same thrust, and therefore it takes much less than to reach a velocity of |
| 46. | ***Integrated Concepts*** *A basketball player jumps straight up for a ball. To do this, he lowers his body 0.300 m and then accelerates through this distance by forcefully straightening his legs. This player leaves the floor with a vertical velocity sufficient to carry him 0.900 m above the floor. (a) Calculate his velocity when he leaves the floor. (b) Calculate his acceleration while he is straightening his legs. He goes from zero to the velocity found in part (a) in a distance of 0.300 m. (c) Calculate the force he exerts on the floor to do this, given that his mass is 110 kg.* |
| Solution | (a)  (b)  (c) |
| 47. | ***Integrated Concepts*** *A 2.50-kg fireworks shell is fired straight up from a mortar and reaches a height of 110 m. (a) Neglecting air resistance (a poor assumption, but we will make it for this example), calculate the shell’s velocity when it leaves the mortar. (b) The mortar itself is a tube 0.450 m long. Calculate the average acceleration of the shell in the tube as it goes from zero to the velocity found in (a). (c) What is the average force on the shell in the mortar? Express your answer in newtons and as a ratio to the weight of the shell.* |
| Solution | (a)  (b)  (c) |
| 48. | ***Integrated Concepts*** *Repeat Exercise 4.47 for a shell fired at an angle  from the vertical.* |
| Solution | (a)  (b)  (c)  (weight of shell included in ) |
| 49. | ***Integrated Concepts*** *An elevator filled with passengers has a mass of 1700 kg. (a) The elevator accelerates upward from rest at a rate of  for 1.50 s. Calculate the tension in the cable supporting the elevator. (b) The elevator continues upward at constant velocity for 8.50 s. What is the tension in the cable during this time? (c) The elevator decelerates at a rate of  for 3.00 s. What is the tension in the cable during deceleration? (d) How high has the elevator moved above its original starting point, and what is its final velocity?* |
| Solution | (a)    (b)  so the tension is:  (c)  (d) |
| 50. | ***Unreasonable Results*** *(a) What is the final velocity of a car originally traveling at 50.0 km/h that decelerates at a rate of  for 50.0 s? (b) What is unreasonable about the result? (c) Which premise is unreasonable, or which premises are inconsistent?* |
| Solution | (a)  (b) It is unreasonable that a car could end up going in the opposite direction by the brakes.  (c)  This is a reasonable coefficient of friction, so what is an unreasonable premise is that the car could decelerate at  for 50 s. This inconsistent with the car having an initial speed of 50 km/h. |
| 51. | ***Unreasonable Results*** *A 75.0-kg man stands on a bathroom scale in an elevator that accelerates from rest to 30.0 m/s in 2.00 s. (a) Calculate the scale reading in newtons and compare it with his weight. (The scale exerts an upward force on him equal to its reading.) (b) What is unreasonable about the result? (c) Which premise is unreasonable, or which premises are inconsistent?* |
| Solution | (a)  Using  gives:    (b) The value (1860 N) is more force than you expect to experience on an elevator.  (c) The acceleration  is much higher than any standard elevator. The final speed is too large (30.0 m/s is VERY fast)! The time of 2.00 s is not unreasonable for an elevator. |

# 4.8 Extended Topic: The four Basic Forces—An Introduction

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| 52. | *(a) What is the strength of the weak nuclear force relative to the strong nuclear force? (b) What is the strength of the weak nuclear force relative to the electromagnetic force? Since the weak nuclear force acts at only very short distances, such as inside nuclei, where the strong and electromagnetic forces also act, it might seem surprising that we have any knowledge of it at all. We have such knowledge because the weak nuclear force is responsible for beta decay, a type of nuclear decay not explained by other forces.* |
| Solution | (a)  (b) |
| 53. | *(a) What is the ratio of the strength of the gravitational force to that of the strong nuclear force? (b) What is the ratio of the strength of the gravitational force to that of the weak nuclear force? (c) What is the ratio of the strength of the gravitational force to that of the electromagnetic force? What do your answers imply about the influence of the gravitational force on atomic nuclei?* |
| Solution | (a)  (b)  (c) . The gravitational force has a very small influence on atomic nuclei. |
| 54. | *What is the ratio of the strength of the strong nuclear force to that of the electromagnetic force? Based on this ratio, you might expect that the strong force dominates the nucleus, which is true for small nuclei. Large nuclei, however, have sizes greater than the range of the strong nuclear force. At these sizes, the electromagnetic force begins to affect nuclear stability. These facts will be used to explain nuclear fusion and fission later in this text.* |
| Solution |  |

# Test Prep for Ap® courses

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| 1. | | CNX_APPhysics_04_M1_track_img  *The figure above represents a racetrack with semicircular sections connected by straight sections. Each section has length d, and markers along the track are spaced d/4 apart. Two people drive cars counterclockwise around the track, as shown. Car X goes around the curves at constant speed v*c*, increases speed at constant acceleration for half of each straight section to reach a maximum speed of 2v*c*, then brakes at constant acceleration for the other half of each straight section to return to speed v*c*. Car Y also goes around the curves at constant speed v*c*, increases its speed at constant acceleration for one-fourth of each straight section to reach the same maximum speed 2v*c*, stays at that speed for half of each straight section, then brakes at constant acceleration for the remaining fourth of each straight section to return to speed v*c*.*  *(a) On the figures below, draw an arrow showing the direction of the net force on each of the cars at the positions noted by the dots. If the net force is zero at any position, label the dot with 0.*  *CNX_APPhysics_04_M1_xy1_img*  *(b)*  *i. Indicate which car, if either, completes one trip around the track in less time, and justify your answer qualitatively without using equations.*  *ii. Justify your answer about which car, if either, completes one trip around the track in less time quantitatively with appropriate equations.* |
| Solution | | CNX_APPhysics_04_M1_xy2_img  Car *X* Car *Y*  i.  Car *X* takes longer to accelerate and does not spend any time traveling at top speed. Car *Y* accelerates over a shorter time and spends time going at top speed. So Car *Y* must cover the straightaways in a shorter time. Curves take the same time, so Car *Y* must overall take a shorter time.  ii.  The only difference in the calculations for the time of one segment of linear acceleration is the difference in distances. That shows that Car *X* takes longer to accelerate. The equation corresponds to Car *Y* traveling for a time at top speed.  4  *c*  *c*  *t*  *d*  *v*    Substituting into the displacement equation in part (b) ii gives . This shows that a car takes less time to reach its maximum speed when it accelerates over a shorter distance. Therefore, Car *Y* reaches its maximum speed more quickly, and spends more time at its maximum speed than Car *X* does, as argued in part (b) i. |
| 2. | | *Which of the following is an example of a body exerting a force on itself?*  (A) a person standing up from a seated position  (B) a car accelerating while driving  (C) both of the above  (D) none of the above |
| Solution | | (d) |
| 3. | | *A hawk accelerates as it glides in the air. Does the force causing the acceleration come from the hawk itself? Explain.* |
| Solution | | A body cannot exert a force on itself. The hawk may accelerate as a result of several forces. The hawk may accelerate toward Earth as a result of the force due to gravity. The hawk may accelerate as a result of the additional force exerted on it by wind. The hawk may accelerate as a result of orienting its body to create less air resistance, thus increasing the net force forward. |
| 4. | | *What causes the force that moves a boat forward when someone rows it?*  (A) The force is caused by the rowers’ arms.  (B) The force is caused by an interaction between the oars and gravity.  (C) The force is caused by an interaction between the oars and the water the boat is traveling in.  (D) The force is caused by friction. |
| Solution | | (c) |
| 5. | | *What object or objects commonly exert forces on the following objects in motion? (a) a soccer ball being kicked, (b) a dolphin jumping, (c) a parachutist drifting to Earth.* |
| Solution | | (a) A soccer player, gravity, air, and friction commonly exert forces on a soccer ball being kicked.  (b) Gravity and the surrounding water commonly exert forces on a dolphin jumping. (The dolphin moves its muscles to exert a force on the water. The water exerts an equal force on the dolphin, resulting in the dolphin’s motion.)  (c) Gravity and air exert forces on a parachutist drifting to Earth. |
| 6. | | *A ball with a mass of 0.25 kg hits a gym ceiling with a force of 78.0 N. What is the net force on the ball?*  (A) 2.50 N downward  (B) 75.5 N downward  (C) 78.0 N downward  (D) 80.5 N downward |
| Solution | | (d) |
| 7. | | *Which of the following is true?*  (A) Earth exerts a force due to gravity on your body, and your body exerts a smaller force on the Earth, because your mass is smaller than the mass of the Earth.  (B) The Moon orbits the Earth because the Earth exerts a force on the Moon and the Moon exerts a force equal in magnitude and direction on the Earth.  (C) A rocket taking off exerts a force on the Earth equal to the force the Earth exerts on the rocket.  (D) An airplane cruising at a constant speed is not affected by gravity. |
| Solution | | (c) |
| 8. | | *Stationary skater A pushes stationary skater B, who then accelerates at 5.0 m/s2. Skater A does not move. Since forces act in action-reaction pairs, explain why Skater A did not move?* |
| Solution | | We can explain this most simply by defining one system as Skater A and the ice. Skater B is outside this system. When Skater A exerts a force on Skater B, Skater B exerts a force equal in magnitude but opposite in direction. As a result, the two systems accelerate away from one another. Skater A exerts a force on the ice by digging in his or her skates, and the ice exerts an equal force in response, but since these forces are internal to the system, no relative movement results. Skater A does not move relative to the ice. |
| 9. | | *The current in a river exerts a force of 9.0 N on a balloon floating in the river. A wind exerts a force of 13.0 N on the balloon in the opposite direction. Draw a free-body diagram to show the forces acting on the balloon. Use your free-body diagram to predict the effect on the balloon.* |
| Solution | | CNX_APPhysics_04_M4_Q22_img  In the diagram, *F*g represents the force due to gravity on the balloon, and *Fb* represents the buoyant force. These two forces are equal in magnitude and opposite in direction. *F*c represents the force of the current. *F*w represents the force of the wind. The net force on the balloon will be  N and the balloon will accelerate in the direction the wind is blowing. |
| 10. | | *A force is applied to accelerate an object on a smooth icy surface. When the force stops, which of the following will be true? (Assume zero friction.)*  (A) The object’s acceleration becomes zero.  (B) The object’s speed becomes zero.  (C) The object’s acceleration continues to increase at a constant rate.  (D) The object accelerates, but in the opposite direction. |
| Solution | | (a) |
| 11. | | *A parachutist’s fall to Earth is determined by two opposing forces. A gravitational force of 539 N acts on the parachutist. After 2 s, she opens her parachute and experiences an air resistance of 615 N. At what speed is the parachutist falling after 10 s?* |
| Solution | | Since , the parachutist has a mass of .  For the first 2 s, the parachutist accelerates at 9.8 m/s2.    Her speed after 2 s is 19.6 m/s.  From 2 s to 10 s, the net force on the parachutist is 539 N – 615 N, or 76 N upward.    Since ,  At 10 s, the parachutist is falling to Earth at 8.4 m/s. |
| 12. | | *A flight attendant pushes a cart down the aisle of a plane in flight. In determining the acceleration of the cart relative to the plane, which factor do you not need to consider?*  (A) The friction of the cart’s wheels.  (B) The force with which the flight attendant’s feet push on the floor.  (C) The velocity of the plane.  (D) The mass of the items in the cart. |
| Solution | | (c) |
| 13. | | *A landscaper is easing a wheelbarrow full of soil down a hill. Define the system you would analyze and list all the forces that you would need to include to calculate the acceleration of the wheelbarrow.* |
| Solution | | The system includes the gardener and the wheelbarrow with its contents. The following forces are important to include: the weight of the wheelbarrow, the weight of the gardener, the normal force for the wheelbarrow and the gardener, the force of the gardener pushing against the ground and the equal force of the ground pushing back against the gardener, and any friction in the wheelbarrow’s wheels. |
| 14. | | *Two water-skiers, with masses of 48 kg and 61 kg, are preparing to be towed behind the same boat. When the boat accelerates, the rope the skiers hold onto accelerates with it and exerts a net force of 290 N on the skiers. At what rate will the skiers accelerate?*  (A) 10.8 m/s2  (B) 2.7 m/s2  (C) 6.0 m/s2 and 4.8 m/s2  (D) 5.3 m/s2 |
| Solution | | (b) |
| 15. | | *A figure skater has a mass of 40 kg and her partner's mass is 50 kg. She pushes against the ice with a force of 120 N, causing her and her partner to move forward. Calculate the pair’s acceleration. Assume that all forces opposing the motion, such as friction and air resistance, total 5.0 N.* |
| Solution | | The system undergoing acceleration is the two figure skaters together.  Net force = .  Total mass = .  Using Newton’s second law, we have that    The pair accelerates forward at 1.28 m/s2. |
| 16. | *An archer shoots an arrow straight up with a force of 24.5 N. The arrow has a mass of 0.4 kg. What is the force of gravity on the arrow?*  (A) 9.8 m/s2  (B) 9.8 N  (C) 61.25 N  (D) 3.9 N | |
| Solution | (d) | |
| 17. | *A cable raises a mass of 120.0 kg with an acceleration of 1.3 m/s2. What force of tension is in the cable?* | |
| Solution | The force of tension must equal the force of gravity plus the force necessary to accelerate the mass.  can be used to calculate the first, and  can be used to calculate the second.  For gravity:    For acceleration:    The total force of tension in the cable is 1176 N + 156 N = 1332 N. | |
| 18. | *A child pulls a wagon along a grassy field. Define the system, the pairs of forces at work, and the results.* | |
| Solution | It is helpful in this situation to define the system as the child and the wagon.  The child applies a force as he or she walks by pressing backward on the Earth. The Earth exerts a force equal in magnitude and opposite in direction. As a result of this net external force, the child moves forward relative to the Earth.  The wagon wheels apply a force backward on the Earth. The Earth exerts a force equal in magnitude and opposite in direction. As a result of this net external force, the wagon moves forward relative to the Earth.  As the child moves forward, the wagon exerts a force backward. The child exerts a force equal in magnitude and opposite in direction to keep the wagon in tow. Since these forces are both internal to the system, the child and the wagon remain stationary relative to each other.  The Earth exerts a force due to gravity on the child and the wagon. The normal force is equal in magnitude and opposite in direction. These external forces balance, and no acceleration up or down results. | |
| 19. | *Two teams are engaging in a tug–of-war. The rope suddenly snaps. Which statement is true about the forces involved?*  (A) The forces exerted by the two teams are no longer equal; the teams will accelerate in opposite directions as a result.  (B) The forces exerted by the players are no longer balanced by the force of tension in the rope; the teams will accelerate in opposite directions as a result.  (C) The force of gravity balances the forces exerted by the players; the teams will fall as a result  (D) The force of tension in the rope is transferred to the players; the teams will accelerate in opposite directions as a result. | |
| Solution | (b) | |
| 20. | *The following free-body diagram represents a toboggan on a hill. What acceleration would you expect, and why?*  G:\Team Drives\CONNEX180067 - College Maintenance 2018-2019\03_Art_Corrections\18_AP_College_Physics\02_021319\98_Current_Art\CNX_APPhysics_04_M5_Q15_img.jpg  (A) Acceleration down the hill; the force due to being pushed, together with the downhill component of gravity, overcomes the opposing force of friction.  (B) Acceleration down the hill; friction is less than the opposing component of force due to gravity.  (C) No movement; friction is greater than the force due to being pushed.  (D) No movement; friction is greater than the sum of the downhill forces. | |
| Solution | (a) | |
| 21. | *Draw a free-body diagram to represent the forces acting on a kite on a string that is floating stationary in the air. Label the forces in your diagram.* | |
| Solution | CNX_APPhysics_04_M5_Q16_img  **F**g is the force on the kite due to gravity.  **F***w* is the force exerted on the kite by the wind.  **F**t is the force of tension in the string holding the kite. It must balance the vector sum of the other two forces for the kite to float stationary in the air. | |
| 22. | *A car is sliding down a hill with a slope of 20°. The mass of the car is 965 kg. When a cable is used to pull the car up the slope, a force of 4215 N is applied. What is the car’s acceleration, ignoring friction?* | |
| Solution | A free-body diagram can be used to represent the situation.  CNX_APPhysics_04_M5_Q20_img  The magnitude of the weight parallel to the slope is    Thus, the net external force is .  Using Newton’s second law, we have that  2  980N  965kg  m  1.02  s  *F*  *a*  *m*  *a*        The car will accelerate up the hill at 1.02 m/s2. | |
| 23. | *A toboggan with two riders has a total mass of 85.0 kg. A third person is pushing with a horizontal force of 42.5 N on a toboggan moving on a horizontal surface at the top of a hill that has a downward angle of 15°. The force of friction on the toboggan is 31.0 N. Which statement describes an accurate free-body diagram to represent the situation?* (A) An arrow of magnitude 10.5 N points down the slope of the hill.  (B) An arrow of magnitude 833 N points straight down.  (C) An arrow of magnitude 833 N points perpendicular to the slope of the hill.  (D) An arrow of magnitude 73.5 N points down the slope of the hill. | |
| Solution | (b) | |
| 24. | *A mass of 2.0 kg is suspended from the ceiling of an elevator by a rope. What is the tension in the rope when the elevator (i) accelerates upward at 1.5 m/s2? (ii) accelerates downward at 1.5 m/s2?*  (A) (i) 22.6 N; (ii) 16.6 N  (B) Because the mass is hanging from the elevator itself, the tension in the rope will not change in either case.  (C) (i) 22.6 N; (ii) 19.6 N  (D) (i) 16.6 N; (ii) 19.6 N | |
| Solution | (a) | |
| 25. | *Which statement is true about drawing free-body diagrams?*  (A) Drawing a free-body diagram should be the last step in solving a problem about forces.  (B) Drawing a free-body diagram helps you compare forces quantitatively.  (C) The forces in a free-body diagram should always balance.  (D) Drawing a free-body diagram can help you determine the net force. | |
| Solution | (d) | |
| 26. | *A basketball player jumps as he shoots the ball. Describe the forces that are acting on the ball and on the basketball player. What are the results?* | |
| Solution | As the player jumps, he exerts a force on Earth. Earth exerts an equal force upward on the player. Since the player is holding the ball, this upward force is also exerted on the ball. As the player shoots the ball, the muscles and bones in his arms are causing a force that propels the ball upward. The ball exerts a force equal in magnitude but opposite in direction on the player, pushing him downward.  As a result, the player accelerates upward, and the ball also accelerates upward. The ball accelerates faster than it would if the player were not also jumping. The player accelerates slower than he would if he were not shooting the ball while he jumps. | |
| 27. | *Two people push on a boulder to try to move it. The mass of the boulder is 825 kg. One person pushes north with a force of 64 N. The other pushes west with a force of 38 N. Predict the magnitude of the acceleration of the boulder. Assume that friction is negligible.* | |
| Solution | A free-body diagram would show a northward force of 64 N and a westward force of 38 N. The net force is equal to the sum of the two applied forces. It can be found using the Pythagorean theorem:    Since ,    The boulder will accelerate at 0.09 m/s2. | |
| 28. | *Which phenomenon correctly describes the direction and magnitude of normal forces?*  (A) electromagnetic attraction  (B) electromagnetic repulsion  (C) gravitational attraction  (D) gravitational repulsion | |
| Solution | (b) | |
| 29. | *Explain which of the four fundamental forces is responsible for a ball bouncing off the ground after it hits, and why this force has this effect.* | |
| Solution | This outcome is due to electromagnetic repulsion between the electrons in atoms. The electrons in the ball repel those in the ground, and vice versa. | |
| 30. | *Which of the basic forces best explains tension in a rope being pulled between two people? Is the acting force causing attraction or repulsion in this instance?*  (A) gravity; attraction  (B) electromagnetic; attraction  (C) weak and strong nuclear; attraction  (D) weak and strong nuclear; repulsion | |
| Solution | (b) | |
| 31. | *Explain how interatomic electric forces produce the normal force, and why it has the direction it does.* | |
| Solution | The outer layers of electrons in the atoms of both an object and the surface with which it is in contact mutually repel each other. Furthermore, while any individual pair of electrons might have a vector that is not perpendicular to the surface, the net sum of all the many, many interactions is perpendicular to the surface. | |
| 32. | *The gravitational force is the weakest of the four basic forces. In which case can the electromagnetic, strong, and weak forces be ignored because the gravitational force is so strongly dominant?*  (A) a person jumping on a trampoline  (B) a rocket blasting off from Earth  (C) a log rolling down a hill  (D) all of the above | |
| Solution | (d) | |
| 33. | *Describe a situation in which gravitational force is the dominant force. Why can the other three basic forces be ignored in the situation you described?* | |
| Solution | When a ball is thrown, gravity is the only one of the four fundamental forces necessary to describe the trajectory. The distances involved are far too large for either of the nuclear forces, and the net electric charge on the ball is zero or so close to it that electromagnetism has no effect. | |

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