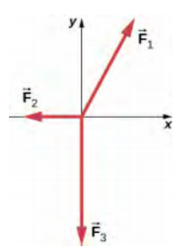
15.7: Newton's Laws of Motion (Exercises)

Conceptual Questions

1. What properties do forces have that allow us to classify them as vectors?
2. Taking a frame attached to Earth as inertial, which of the following objects cannot have inertial frames attached to them, and which are inertial reference frames?
   a. A car moving at constant velocity
   b. A car that is accelerating
   c. An elevator in free fall
   d. A space capsule orbiting Earth
   e. An elevator descending uniformly
3. A woman was transporting an open box of cupcakes to a school party. The car in front of her stopped suddenly; she applied her brakes immediately. She was wearing her seat belt and suffered no physical harm (just a great deal of embarrassment), but the cupcakes flew into the dashboard and became “smushcakes.” Explain what happened.
4. Why can we neglect forces such as those holding a body together when we apply Newton’s second law?
5. A rock is thrown straight up. At the top of the trajectory, the velocity is momentarily zero. Does this imply that the force acting on the object is zero? Explain your answer.
6. Identify the action and reaction forces in the following situations:
   a. Earth attracts the Moon,
   b. a boy kicks a football,
   c. a rocket accelerates upward,
   d. a car accelerates forward,
   e. a high jumper leaps, and
   f. a bullet is shot from a gun.
7. Suppose that you are holding a cup of coffee in your hand. Identify all forces on the cup and the reaction to each force.
8. (a) Why does an ordinary rifle recoil (kick backward) when fired? (b) The barrel of a recoilless rifle is open at both ends. Describe how Newton’s third law applies when one is fired. (c) Can you safely stand close behind one when it is fired?

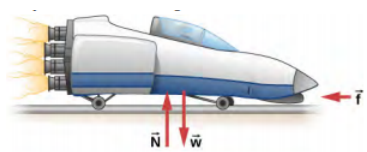
Problems

9. Two ropes are attached to a tree, and forces of $\vec{F}_1 = 2.0\,\hat{i} + 4.0\,\hat{j}$ N and $\vec{F}_2 = 3.0\,\hat{i} + 6.0\,\hat{j}$ N are applied. The forces are coplanar (in the same plane). (a) What is the resultant (net force) of these two force vectors? (b) Find the magnitude and direction of this net force.
10. A telephone pole has three cables pulling as shown from above, with $\vec{F}_1 = (300.0\,\hat{i} + 500.0\,\hat{j})$, $\vec{F}_2 = -200.0\,\hat{i}$, and $\vec{F}_3 = -800.0\,\hat{j}$. (a) Find the net force on the telephone pole in component form. (b) Find the magnitude and direction of this net force.

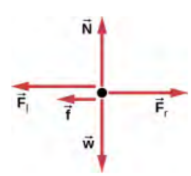


11. Two teenagers are pulling on ropes attached to a tree. The angle between the ropes is 30.0°. David pulls with a force of 400.0 N and Stephanie pulls with a force of 300.0 N. (a) Find the component form of the net force. (b) Find the magnitude of the resultant (net) force on the tree and the angle it makes with David’s rope.
12. Two forces of $\vec{F}_1 = 75.0\ 2\,(\hat{i} - \hat{j})$ N and $\vec{F}_2 = \frac{150.0}{\sqrt{2}}(\hat{i} - \hat{j})$ N act on an object. Find the third force $\vec{F}_3$ that is needed to balance the first two forces.

13. While sliding a couch across a floor, Andrea and Jennifer exert forces $\vec{F}_A$ and $\vec{F}_J$ on the couch. Andrea's force is due north with a magnitude of 130.0 N and Jennifer's force is 32° east of north with a magnitude of 180.0 N. (a) Find the net force in component form. (b) Find the magnitude and direction of the net force. (c) If Andrea and Jennifer's housemates, David and Stephanie, disagree with the move and want to prevent its relocation, with what combined force $\vec{F}_{DS}$ should they push so that the couch does not move?
14. Andrea, a 63.0-kg sprinter, starts a race with an acceleration of 4.200 m/s^2. What is the net external force on her?
15. 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 of his cart's acceleration.
16. Astronauts in orbit are apparently weightless. This means that a clever method of measuring the mass of astronauts is needed to monitor their mass gains or losses, and adjust their diet. 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 an astronaut's acceleration is measured to be 0.893 m/s^2. (a) Calculate her mass. (b) By exerting a force on the astronaut, the vehicle in which she orbits experiences an equal and opposite force. Use this knowledge to find an equation for the acceleration of the system (astronaut and spaceship) that would be measured by a nearby observer. (c) Discuss how this would affect the measurement of the astronaut's acceleration. Propose a method by which recoil of the vehicle is avoided.
17. In Figure 5.4.3, the net external force on the 24-kg mower is given as 51 N. If the force of friction opposing the motion is 24 N, what force F (in newtons) is the person exerting on the mower? Suppose the mower is moving at 1.5 m/s when the force F is removed. How far will the mower go before stopping?
18. The rocket sled shown below decelerates at a rate of 196 m/s^2. What force is necessary to produce this deceleration? Assume that the rockets are off. The mass of the system is 2.10×10^3 kg.

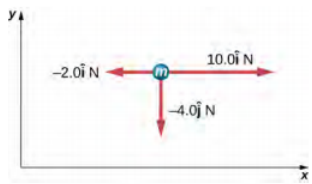


19. If the rocket sled shown in the previous problem starts with only one rocket burning, what is the magnitude of this acceleration? Assume that the mass of the system is 2.10×10^3 kg, the thrust T is 2.40×10^4 N, and the force of friction opposing the motion is 650.0 N. (b) Why is the acceleration not one-fourth of what it is with all rockets burning?
20. What is the deceleration of the rocket sled if it comes to rest in 1.10 s from a speed of 1000.0 km/h? (Such deceleration caused one test subject to black out and have temporary blindness.)
21. 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 exerts 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? (See the free-body diagram.) (b) Calculate the acceleration. (c) What would the acceleration be if friction were 15.0 N?



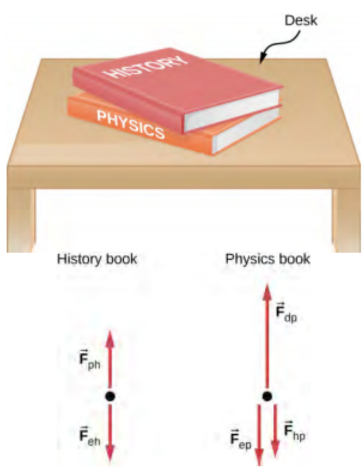
22. A powerful motorcycle can produce an acceleration of 3.50 m/s^2 while traveling at 90.0 km/h. At that speed, the forces resisting motion, including friction and air resistance, total 400.0 N. (Air resistance is analogous to air friction. It always opposes the motion of an object.) What is the magnitude of the force that motorcycle exerts backward on the ground to produce its acceleration if the mass of the motorcycle with rider is 245 kg?
23. A car with a mass of 1000.0 kg accelerates from 0 to 90.0 km/h in 10.0 s. (a) What is its acceleration? (b) What is the net force on the car?
24. The driver in the previous problem applies the brakes when the car is moving at 90.0 km/h, and the car comes to rest after traveling 40.0 m. What is the net force on the car during its deceleration?
25. An 80.0-kg passenger in an SUV traveling at 1.00×10^2 km/h is wearing a seat belt. The driver slams on the brakes and the SUV stops in 45.0 m. Find the force of the seat belt on the passenger.

26. A particle of mass 2.0 kg is acted on by a single force $\vec{F}_1 = 18\ \hat{i}$ N. (a) What is the particle's acceleration? (b) If the particle starts at rest, how far does it travel in the first 5.0 s?
27. Suppose that the particle of the previous problem also experiences forces $\vec{F}_2 = -15\ \hat{i}$ N and $\vec{F}_3 = 6.0\ \hat{j}$ N. What is its acceleration in this case?
28. Find the acceleration of the body of mass 5.0 kg shown below. Use column vectors to express your answer.



29. In the following figure, the horizontal surface on which this block slides is frictionless. If the two forces acting on it each have magnitude F = 30.0 N and M = 10.0 kg , what is the magnitude of the resulting acceleration of the block?

30. (a) What net external force is exerted on a 1100.0-kg artillery shell fired from a battleship if the shell is accelerated at 2.40×10^4 m/s^2? (b) What is the magnitude of the force exerted on the ship by the artillery shell, and why?
31. A brave but inadequate rugby player is being pushed backward by an opposing player who is exerting a force of 800.0 N on him. The mass of the losing player plus equipment is 90.0 kg, and he is accelerating backward at 1.20 m/s^2. (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 110.0 kg?
32. A history book is lying on top of a physics book on a desk, as shown below; a free-body diagram is also shown. The history and physics books weigh 14 N and 18 N, respectively. Identify each force on each book with a double subscript notation (for instance, the contact force of the history book pressing against physics book can be described as $\vec{F}_{HP}$), and determine the value of each of these forces, explaining the process used.



33. A truck collides with a car, and during the collision, the net force on each vehicle is essentially the force exerted by the other. Suppose the mass of the car is 550 kg, the mass of the truck is 2200 kg, and the magnitude of the truck's acceleration is 10 m/s^2. Find the magnitude of the car's acceleration.
34. A ball of mass m hangs at rest, suspended by a string. Draw the free-body diagram for the ball.
35. A car moves along a horizontal road. Draw a free-body diagram; be sure to include the friction of the road that opposes the forward motion of the car.
36. A Formula One race car is traveling at 89.0 m/s along a straight track enters a turn on the race track with radius of curvature of 200.0 m. What centripetal acceleration must the car have to stay on the track?

37. A particle travels in a circular orbit of radius 10 m. Its speed is changing at a rate of 15.0 m/s^2 at an instant when its speed is 40.0 m/s. What is the magnitude of the acceleration of the particle?
38. The driver of a car moving at 90.0 km/h presses down on the brake as the car enters a circular curve of radius 150.0 m. If the speed of the car is decreasing at a rate of 9.0 km/h each second, what is the magnitude of the acceleration of the car at the instant its speed is 60.0 km/h?
39. A race car entering the curved part of the track at the Daytona 500 drops its speed from 85.0 m/s to 80.0 m/s in 2.0 s. If the radius of the curved part of the track is 316.0 m, calculate the total acceleration of the race car at the beginning and ending of reduction of speed.

Contributors and Attributions

Samuel J. Ling (Truman State University), Jeff Sanny (Loyola Marymount University), and Bill Moebs with many contributing authors. This work is licensed by OpenStax University Physics under a Creative Commons Attribution License (by 4.0).