For Thought and Discussion
1. Under what conditions is the magnitude of the vector sum \( \mathbf{A} + \mathbf{B} \) equal to the sum of the magnitudes of the two vectors? 
2. Can two vectors of equal magnitude sum to zero? Can two vectors of unequal magnitude sum to zero? 
3. Repeat Question 1 for the dot product of two vectors. 
4. Three vectors sum to zero. If they are placed head to tail, what geometric figure must they form? Explain. 
5. Is it meaningful to talk about vectors without mentioning coordinate systems or components? 
6. Can an object have a southward acceleration while moving northward? What is the acceleration of the earth as it moves northward? 
7. Is there any way to negotiate a curved path without accelerating? 
8. A satellite glides through space at a steady 29,000 km in a circular orbit around Earth. Is the satellite accelerating? If so, in what direction? If not, why not? 

Exercises and Problems
36/ Exercises 
Section 3.1 Vectors
1. 17. You walk 220 m and then north 150 m. What are the magnitude and direction of your displacement vector?
2. 18. An ion in a mass spectrometer (a device that sorts atomic species) forms a semicircular path of radius 15.2 cm. What are (a) the distance it travels and (b) the magnitude of its displacement vector?
3. 19. A migrating whale follows the west coast of Mexico and North America toward its summer home in Alaska. It first travels 360 km due northwest to just off the coast of northern California and then turns due north and travels 400 km toward its destination. Determine graphically the magnitude and direction of its displacement vector.
4. 20. A city’s streets are laid out with its north-south blocks as long as its east-west blocks. You walk 8 blocks east and 3 blocks north. Determine (a) the total distance you walk and (b) the magnitude of your displacement vector. Express answers in units of east-west blocks.
5. 21. Vector \( \mathbf{A} \) has magnitude 3.0 m and points to the right; vector \( \mathbf{B} \) has magnitude 4.0 m and points vertically upward. Find the magnitude and direction of a vector \( \mathbf{C} \) such that \( \mathbf{A} + \mathbf{B} + \mathbf{C} = 0 \).
6. 22. Vector \( \mathbf{U} \) represents a displacement of 120 km at 29° counterclockwise from the x-axis. Vector \( \mathbf{V} \) has magnitude 45 km in a unit vector notation.
7. 23. Find the magnitude of the vector \( \mathbf{3U} + \mathbf{13} \mathbf{V} \) and determine the angle it makes with the x-axis.
8. 24. (a) What is the magnitude of \( \mathbf{17} \mathbf{B} \)? (b) What angle does it make with the x-axis?

Section 3.2 Velocity and Acceleration Vectors
25. An astronomer is discovered heading straight toward Earth at 15 km/s. An international team manages to attach a giant rocket engine to the asteroid. The rocket fires for 10 min, after which the asteroid is moving at 28° to its original path at a speed of 19 km/s and a acceleration of 500 km/s². 
26. An object is moving at 18 m/s at an angle of 220° counterclockwise from the x-axis. What are the \( x \) and \( y \) components of its velocity?
27. A car drives north at 40 m/s for 10 min and then turns east and goes 5.0 m at 60 m/s. Finally, it goes southwest at 30 m/s for 6.0 m. Draw a vector diagram and determine (a) the car’s displacement and (b) its average velocity for this trip.

37/ Problems 
48. Vector \( \mathbf{A} \) and \( \mathbf{B} \) have the same magnitude \( A \) and are at right angles. Find the magnitude of the vectors (a) \( \mathbf{A} + \mathbf{B} \) and (b) \( \mathbf{A} \cdot \mathbf{B} \).
49. Vector \( \mathbf{A} \) has magnitude 1.0 m and is at an angle to the \( x \)-axis of 30° from the x-axis. Vector \( \mathbf{B} \) has magnitude 1.8 m. What angle should \( \mathbf{B} \) make with the x-axis so that \( \mathbf{A} + \mathbf{B} \) is purely vertical?
50. Let \( \mathbf{A} = -15 \mathbf{i} - 40 \mathbf{j} \) and \( \mathbf{B} = 33 \mathbf{i} + 11 \mathbf{j} \). Find a vector \( \mathbf{C} \) such that \( \mathbf{A} + \mathbf{B} + \mathbf{C} = 0 \).

Section 3.3 Projectile Motion
39. You toss an apple horizontally at 8.7 m/s from a height of 2.6 m. Simultaneously, you drop a peach from the same height. How long does each take to reach the ground? 
40. A carpenter tosses a shingle off an 8.5-m-high roof, giving it an initial horizontal velocity of 11 m/s. (a) How long does it take the shingle to reach the ground? (b) How far does it move horizontally in this time? 
41. A ball rolls horizontally at 41 m/s travels 23 m horizontally before it hits the ground. From what height was it fired? 
42. Ink droplets in a inkjet printer are ejected horizontally at 12 m/s from a print head. How far does a 1.0 mm dot to the page? Here \( \frac{1}{100} \) in. = 0.025 cm. 
43. Protons in a particle accelerator drop 1.2 m above the 1.7 km length of the accelerator. What is their approximate average speed? 
44. If you can hit a golf ball 180 m on Earth, how far can you hit it on the Moon? (Your answer is an underestimate because the distance on Earth is restricted by air resistance as well as by a larger gravity.)
45. If you are on the Moon and your spacecraft fires a rocket at 200 m/s, do the rockets hit each other? 
46. How fast is it possible for an object to be moving in one direction but accelerating in another? 

55. The sweep-second hand of a clock is 3.1 cm long. What are the magnitude of (a) the average velocity and (b) the average acceleration of the tip's motion over 5.4 s intervals? (c) What is the angle between the average velocity and acceleration vectors? 
56. A ferryboat sails between two towns directly opposite each other on a river. If the boat sails at 15 km/h relative to the water at a constant speed of 6.3 km/h, what angle should the boat head? 
57. The sum, \( \mathbf{A} + \mathbf{B} \), of two vectors is perpendicular to the difference, \( \mathbf{A} - \mathbf{B} \). What is the angle between \( \mathbf{A} \) and \( \mathbf{B} \)? 
58. Write an expression for a unit vector that lies at 45° between the positive x and y axes.
59. An object is moving horizontally in a direction at 4.5 m/s, when an acceleration is applied in the y-direction for a period of 18 s. If the object moves equal distances in the x and y directions during this time, what is the magnitude of its acceleration? 
60. A particle leaves the origin with initial velocity \( \mathbf{v}_0 = (1.5, 1.5) \) m/s. Under a constant acceleration given by \( \mathbf{a} = -1.2 - 0.26 \mathbf{j} \) m/s². What does the particle cross the y-axis? (b) What is its coordinate at the time? (c) How fast is it moving and in what direction, at that time? 
61. A fast flowing water horizontal from a spout gun held 1.6 m above the ground. It hits another kid 2.1 m away in a square shape, at a point 0.93 m above the ground. What was the initial speed of the water?
62. In a chase-scene, a movie stuntman is supposed to run right off the flat roof of one city building and land on another roof 1.9 m lower. If the gap between the buildings is 4.5 m wide, how fast must he run?
63. Standing on the ground 3.0 m from the wall of a building, you want to throw a package from your 1.5-m shoulder level to someone in a second-floor window 2.4 m above the ground. At what speed should you throw the package so it just barely reaches the window? 
64. Derive a general formula for the horizontal distance covered by a projectile launched vertically at speed \( v \), from height \( A \).
65. Compare the travel times for the projectiles launched at 30° and 60°. 
66. In Fig. 3.19, both of which have the same starting and ending points. 
67. You toss a softball at 29° slope, as shown in Fig. 3.23. Determine the initial velocity vector so that the chocolate bar will reach your friend moving horizontally.
Answers to Chapter Questions

Answer to Chapter Opening Question
Assuming negligible air resistance, the penguin should leave the water at a 45° angle.

Answers to GOF IT? Questions
3.1 (c)
3.2 (d) only
3.3 (c) given the greatest change in speed; (b) gives the greatest change in direction.

4.1 The Wrong Question
We began this chapter with two questions: one about why a spacecraft moved and the other about why a baseball’s motion changed. For nearly 2000 years following the work of Aristotle (384–322 B.C.), the first question—Why do things move?—was the crucial one.
Section 4.2 Newton's First and Second Laws

13. A subway train has a mass of 1.5 x 10^6 kg. What force is required to accelerate the train at 0.5 m/s^2? 5.25 x 10^6 N

14. A railroad locomotive with a mass of 6.1 x 10^6 kg can exert a force of 1.2 x 10^7 N at 0.05 m/s^2. If the train is being pulled along by a locomotive, what force is necessary? 3.0 x 10^7 N

15. A small plane starts down the runway with acceleration of 7.2 m/s^2. If the force provided by its engine is 1.1 x 10^7 N, what is the plane's mass?

16. A car leaves the road traveling at 101 km/h and hits a tree, coming to a complete stop in 14 t. What average force does a seat belt exert on a 60 kg passenger during this collision? 8.4 x 10^3 N

17. By how much does the force required to stop a car increase if the initial speed is doubled and the stopping distance remains the same?

18. A 3800 kg jet touches down at 240 km/h on the deck of an aircraft carrier and immediately deploys a parachute to slow itself down. If the plane comes to a stop in 170 m, what is the average force of air on the parachute? Assume the parachute provides essentially all of the stopping force.

19. Starting from rest, a 940 kg racing car reaches 400 m in 4.9 s. What is the average force acting on the car?

20. In an endurance-crop driving contest, a student enacts an 85-kg e in a strawberry field. The force on the egg is not exerted in exactly 1.5 N, and if the block hits the ground at 1.2 m/s, by how much must the stopping force be changed in order to stop the car?

21. In a front-end collision, a 1300 kg car with shock-absorbing bumpers can withstand a maximum force of 65 kN before damage occurs. If the maximum permitted for non-occupant collision is 10 kN, by how much must the bumper be able to move relative to the car?

Section 4.4 The Force of Gravity

22. Show that the universal acceleration can be written as g = N kg. Why does it make sense to give a 9.8 N/kg? When talking about mass and weight?

23. My spaceship crashes on one of the Sun's nine planets. Fortunately, the ship's scales are intact and show that my weight is 322 N. If I know my mass is 60 kg, where am I? Please Consult Appendix E.

24. A barefoot astronaut kicks a ball across the area recreation of a space station. Does the ball's apparent weightlessness mean the astronaut's two don't get hurt? Explain.

25. The surface gravity of Jupiter's moon is one-fifth that of Earth. What would happen to your weight and to your mass if you were to travel in 55 m/s on Earth?

26. In a tunnel, you push water backward with your paddle. What force actually propels the canoe forward?

27. It is possible for aavanaugh set force to act on an object without the object's speed changing. Explain.

28. As a child, you tie your skis to your boots to prevent them from coming off. Do they hang vertically? Explain.

29. If passengers in my car sit at the back of the car, explaining that I believe in the law of inertia. What's that got to do with seatbelts?

Exercises

Section 4.5 Using Newton's Second Law

30. A 50-kg parachute jumper descends at a steady 40 km/h. What is the force of the air on the parachute?

31. A 930 kg motorboat accelerates away from a dock at 2.3 m/s^2. Its propeller provides a thrust force of 3.9 kN. What drag force is exerted by the water on the boat?

32. An elevator accelerates downward at 2.4 m/s^2. What force does the floor of the elevator exert on a 52-kg passenger?

33. What is the general vertical force on a 747 jetliner when the plane is (a) flying at constant altitude and (b) accelerating upward at 1.1 m/s^2? The aircraft's mass is 4.5 x 10^5 kg.

34. A golf ball is hit with a 6 degree 540 m/s. What is the upward force during this acceleration time compared with your weight?

35. What upward gravitational force does a 5600-kg elephant exert on Earth?

36. I have a mass of 65 kg. If I jump off a 120-cm-high table, how far does the ball move after I leave the table? 1.5 m

37. What force is necessary to stretch a spring 48 cm, if the spring constant is 270 N/m?

38. A 35 N force is applied to a spring with spring constant k = 220 N/m. How much does the spring stretch?

39. A spring with spring constant k = 340 N/m is used to weight a 6.7 kg fish. How far does the spring stretch?
mass is constant. Consider an object whose mass may be changing, and show that the rule for the derivative of a product (see Appendix A) can be used to write Newton's law in the form

\[ F = ma + \frac{\text{d}m}{\text{d}t} \]

5.75b A railroad car is being pulled beneath a grain elevator that damps grain at the rate of 450 kg/s. Use the result of Problem 58 to find the force that must be applied to keep the car moving at a constant 2.0 m/s.

60. A block 30% more massive than you hangs from a rope. The other end of the rope goes over a massless, frictionless pulley, and dangles freely. What is the acceleration of the block? Use the free-body diagram of the rope to show that the tension T equals the force of gravity, and that Newton's second law for the block gives

\[ F = ma \]

5.79b A 65 kg person stands on a scale in a moving elevator while holding a 5 kg mass suspended from a massless spring with spring constant 0.8 kN/m. None of the objects is the elevator is moving relative to the elevator, but the spring is stretched by 5 cm. (a) Is the elevator accelerating, and if so, what are the magnitude and direction of its acceleration? (b) What is the reading of the scale on which the person stands?

65. A block of mass M kg hangs from a uniform rope of length L and mass m. Find an expression for the tension in the rope as a function of the distance y measured vertically downward from the top of the rope.

67. Einstein's special theory of relativity, the momentum of a particle is given by

\[ p = \frac{m \cdot v}{\sqrt{1 - \frac{v^2}{c^2}}} \]

where the mass m and speed of light c are constants, and v is the particle’s speed. For such a particle moving in one dimension along a straight line, Equation 4.3 no longer applies. How does the general form of Newton’s second law, Equation 4.2, relate the net force to the direction of motion to the acceleration, a = d²v/dt²?

68. Your science fiction-writing friend is working on a screenplay concerning a civilization that lives on a neutron star (10 km in diameter and extremely massive). Your friend decided the people would have an average mass of 75 kg but does not know how much they should weigh in pounds. An astrophysicist tells you the acceleration due to gravity on a typical neutron star is 5.73 x 10⁶ m/s². What is the weight of the inhabitants of this strange world?

69. You read about a car accident in a newspaper. A car traveling at 70 km/h collided with a concrete bridge support. The front end of the car was compressed 0.94 m, and the car came to a complete stop within this distance. You wonder, How many "g"s" of acceleration did the occupant of the car experience? Here, "g" is the acceleration due to gravity. The acceleration is 9.8 m/s². The occupant of the car experiences an acceleration to 9.8 m/s².

70. You and your lab partner devise a clever experiment to measure the If the force is applied to a ball when it is thrown. You throw a 200-g ball vertically upward. A high-speed video image of the throw indicates your hand pushed on the ball for 0.32 s. The ball rises to a maximum height of 7.25 m above your hand. What force did you apply?

**Answers to Chapter Questions**

**Chapter 4 Opening Question**

The human body exerts a contact force; wind and water are fluids that exert pressure forces, and gravity is an action-at-a-distance force between Earth and the sailboat.

**Answers to GOT IT? Questions**

4.1 (b)
4.2 No. Look at Fig. 4.5b.
4.3 All would move in straight lines.
4.4 (a) greater; (b) less; (c) less; (d) greater; (e) equal
4.5 (c) less than 2 N
6 (a) No, the acceleration is still 0; (b) no, the direction of velocity is irrelevant (this situation would occur if the helicopter were moving downward but slowing).

5.1 Using Newton’s Second Law

Newton’s second law, \( F = ma \), is the cornerstone of mechanics. We can use it to develop faster skis, engineer skyscrapers, design safer roads, compute a rocket’s thrust, and solve myriad other practical problems.

We’ll work Example 5.1 in great detail, applying Problem Solving Strategy 4.1. Follow this example closely, and try to understand how our solution is grounded in Newton’s basic statement that the net force on an object determines that object’s acceleration.