

Q1-9 On a $v-t$ graph, the slope equals the _____.

Q1-10 The velocity change equals the area under the _____ graph.

Q1-11 The displacement equals the area under the _____ graph.

Q1-12 In air, a rock falls faster than a feather because of _____.

Q1-13 When an object thrown straight upward reaches its greatest height, its velocity is _____ and its acceleration is _____.

EXERCISES

The student should work out some of the exercises for each section to test his or her general understanding of the concepts before attempting the problems. Answers to most of the odd-numbered exercises and problems are given at the end of the book, usually to three significant figures. If your answers differ slightly in the last place, this may be due to differences in rounding off intermediate results, rather than to an error in your work. Solutions to half the odd-numbered exercises appear in the Study Guide.

Section 1.1 | Measurements, Standards, Units, and Errors

1-1 An acre is 43,560 ft². How large is this in square metres (m²)?

1-2 Convert 40 mi h⁻¹ to metres per second (m s⁻¹).

1-3 A gallon is 231 cubic inches (in.³), and a litre is 1000 cm³. How many litres are there in a gallon?

1-4 A furlong is 220 yards, and a fortnight is 14 days. If a snail moves at 2 m h⁻¹, what is this in furlongs per fortnight?

1-5 A cell membrane is 70 angstrom (Å) units thick. If an angstrom unit is 10⁻¹⁰ m, what is the membrane thickness in (a) metres; (b) micrometres?

1-6 If two quantities have different dimensions, can they be (a) multiplied; (b) added? Give examples to support your answers.

1-7 In the United States land is measured in acres (1 acre = 43,560 ft²). In most other countries it is measured in hectares (1 hectare = 10⁴ m²). How large is a 100-acre farm in hectares?

1-8 The volumes of reservoirs are sometimes measured in acre-feet; that is, a lake with an area of 1 acre and an average depth of 1 ft contains 1 acre-foot of water. If a lake has an area of 100 acres and an average depth of 20 ft, find its volume (a) in acre-feet; (b) in cubic feet; (c) in cubic metres. (1 acre = 43,560 ft²)

1-9 Suppose you wanted to know the area of a rectangular room and had a cloth tape measure available to determine its dimensions. What are some random and systematic errors that might affect your result?

1-10 A driver wishes to check the speedometer by traveling at a constant speed along a highway with markers placed every kilometre and having a passenger note the time intervals with a wrist-watch. Discuss the random and systematic errors involved.

1-11 If a dollar is 7.2 francs, and a 0.75-litre bottle of wine costs 20 francs, how much does it cost in dollars per quart?

1-12 A U.S. gallon is 231 in.³. An Imperial gallon, used sometimes in England and in the British Commonwealth, is 277.42 in.³. In Niagara Falls, New York, gasoline is \$1.08 (U.S.) per U.S. gallon. Across the international bridge in Niagara Falls, Ontario, gasoline is \$1.80 (Canadian) per Imperial gallon. If \$1.00 (Canadian) = \$0.72 (U.S.), on which side is gasoline cheaper, and by what percentage?

Section 1.2 | Displacement; Average Velocity

1-13 A car travels 30 km in 45 min on a straight highway. What is its average velocity in kilometres per hour (km h⁻¹)?

1-14 A pilot wishes to fly 2000 km in 4 h. What average velocity in metres per second is required to accomplish this?

1-15 Sketch the position-versus-time graph for a car that starts from rest and is driven 1 km to a store. (Describe the motion in words.)

1-16 A car travels in a straight line at 40 km h⁻¹ for 1 h and at 60 km h⁻¹ for 2 h. (a) How far does it travel? (b) Find the average velocity.

1-17 A woman wants to drive 100 km in 2 h. If she averages 40 km h⁻¹ for the first 1.5 h, what average velocity must she maintain for the remaining time?

1-18 A man runs a 42-km marathon in 2.5 h. Find the average velocity in (a) kilometres per hour (km h^{-1}); (b) metres per second (m s^{-1}).

1-19 A sprinter runs the 100-m dash in 9.8 s. (a) What is the sprinter's average velocity? (b) Since the runner starts from rest, the velocity cannot be constant. Sketch the approximate position-versus-time graph for the runner. Explain the assumptions made.

1-20 Light travels at $3 \times 10^8 \text{ m s}^{-1}$. A light-year is the distance light travels in 1 year, 365 days. Find the distance in kilometres to the nearest star, which is 4 light-years away from us.

1-21 A falling object moves so that its height x above the ground at time t is given by the equation $x = 100 \text{ m} - (4.9 \text{ s}^{-2})t^2$. Find its average velocity from (a) $t = 0$ to $t = 2 \text{ s}$; (b) $t = 2$ to $t = 4 \text{ s}$.

1-22 A ball thrown straight upward has a height x above the ground which is given by the equation $x = (19.6 \text{ m s}^{-1})t - (4.9 \text{ m s}^{-2})t^2$. Find the average velocity from (a) $t = 0$ to $t = 2 \text{ s}$; (b) $t = 2$ to $t = 4 \text{ s}$.

1-23 From the position-versus-time graph of Fig. 1.13, find the average velocity from $t = 0 \text{ s}$ to (a) $t = 10 \text{ s}$; (b) $t = 20 \text{ s}$; (c) $t = 40 \text{ s}$.

1-24 A baseball reaches a batter at 40 m s^{-1} . If home plate is 0.3 m across, how long will the ball be over the plate?

1-25 In 1970, a record was set when a swimmer swam 100 m in 51.9 s. What was his average velocity in km h^{-1} ?

Section 1.3 | Instantaneous Velocity

1-26 In a period of 4 h, a man walks 10 km north, turns around, and walks 6 km south. Find his (a) average velocity; (b) average speed.

1-27 John drives 100 km at 100 km h^{-1} and then drives an additional 100 km at 80 km h^{-1} . Mary makes the same 200 km trip at a constant speed of 90 km h^{-1} . (a) If they leave at the same time, who (if either) will complete the trip first? (b) By how much time will he or she beat the other driver?

1-28 In Fig. 1.13, what is the instantaneous velocity at (a) $t = 5 \text{ s}$; (b) $t = 15 \text{ s}$; (c) $t = 25 \text{ s}$; (d) $t = 35 \text{ s}$?

1-29 Draw the instantaneous velocity-versus-time graph corresponding to Fig. 1.13.

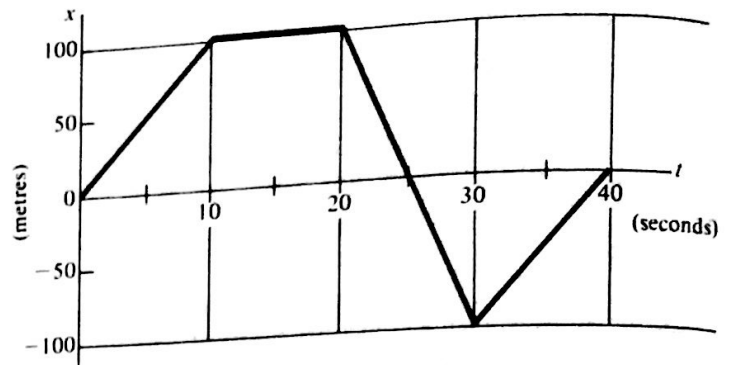


Figure 1.13. Exercises 1-23, 1-28, and 1-29.

1-30 Figure 1.14 shows the position of a pendulum versus time. In the interval $t = 0$ to T , when is the velocity (a) zero; (b) positive; (c) negative?

1-31 Figure 1-31 shows the position of a pendulum versus time. In the interval from $t = 0$ to T , when does the velocity have its largest positive and negative values?

1-32 In 1875, Matthew Webb became the first man to swim the English Channel without a life jacket. He required 21 h and 45 min to make the 33.8-km crossing. (a) What was his average velocity in km h^{-1} ? (b) Since he did not swim in a straight line, he actually covered a distance of 60 km. What was his average speed?

1-33 The maximum speed attained by a runner during a 100-m race is reported as 12.5 m s^{-1} . He completed the race in 9.9 s. Are these numbers consistent? Explain.

Section 1.4 | Acceleration

1-34 A car proceeds to pass another. Its speed increases from 50 to 100 km h^{-1} in 4 s. What is the average acceleration?

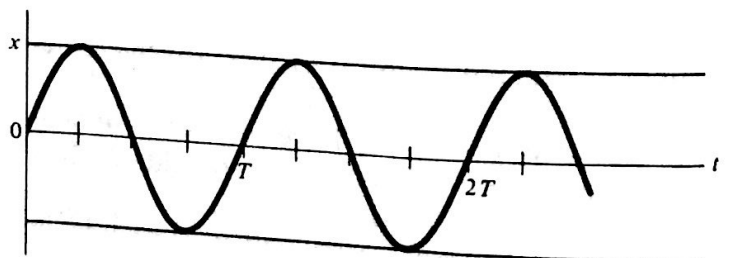


Figure 1.14. The horizontal position of a pendulum versus time. Exercises 1-30 and 1-31; Problem 1-79.

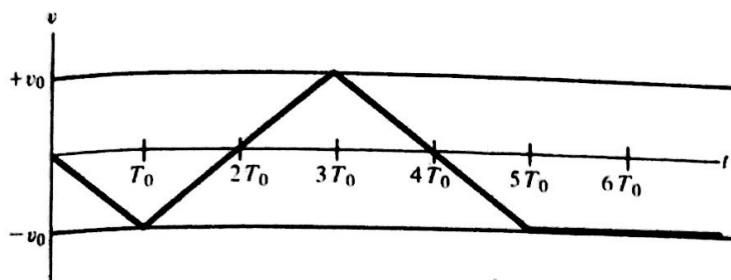


Figure 1.15. Exercises 1-36 and 1-37.

1-35 A car moves at a constant velocity of 50 m s^{-1} for 20 s. It then slows with a constant acceleration, coming to rest 10 s later. (a) Draw a velocity-time graph for the car. (b) Draw the acceleration-time graph for the car.

1-36 Draw the acceleration-versus-time graph corresponding to Fig. 1.15.

1-37 When does the acceleration corresponding to Fig. 1.14 have (a) a maximum value; (b) a minimum value; (c) a value of zero?

1-38 A car initially moving at 20 m s^{-1} brakes with an acceleration of 2 m s^{-2} . How long will it take for the car to stop?

Section 1.5 | Finding the Motion of an Object

1-39 A baseball player hits a pitched ball so that its velocity reverses direction and its speed changes from 30 m s^{-1} to 40 m s^{-1} . The bat moves at an average velocity of 30 m s^{-1} , and it is in contact with the ball for a distance of 0.05 m. (a) For how long are the bat and ball in contact? (b) What is the average acceleration of the ball while it is in contact with the bat?

1-40 A soccer player kicks a ball that is initially at rest on the ground. The player is in contact with the ball for 0.008 s, and the ball leaves his foot at a velocity of 32 m s^{-1} . What was the ball's average acceleration during the kick?

1-41 A spaceship is launched from the moon with an acceleration of 0.1 m s^{-2} . How long will it take the spaceship to achieve a velocity of 10^4 m s^{-1} ?

1-42 An electron in a hydrogen atom has a speed of roughly $3 \times 10^6 \text{ m s}^{-1}$. (a) How long will it take the electron to travel a typical atomic distance, 10^{-10} m ? (b) If the speed is constant but the velocity reverses direction in that time interval, what is the average acceleration?

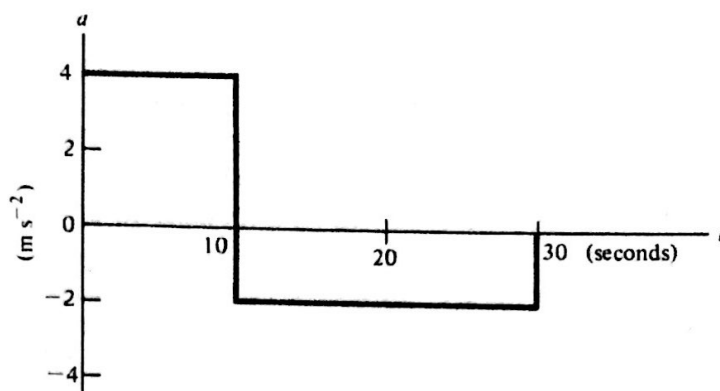


Figure 1.16. Exercise 1-46.

1-43 A jet plane accelerates on a runway from rest at 4 m s^{-2} . After 5 s, find its (a) distance traveled; (b) velocity.

1-44 In the accelerator shown in Fig. 1.1, protons emerge with a velocity of $2.5 \times 10^8 \text{ m s}^{-1}$. The accelerator is 0.8 km long. (a) If the acceleration is uniform, how large is it? (b) How long does it take for protons to travel the length of the accelerator?

1-45 A train traveling with a velocity of 30 m s^{-1} stops with a uniform acceleration in 50 s. (a) What is the acceleration of the train? (b) What is the distance traveled before coming to rest?

1-46 A car starts from rest at $t = 0$ and accelerates as shown in Fig. 1.16. Find its velocity at (a) $t = 10 \text{ s}$; (b) $t = 30 \text{ s}$. (c) Draw the velocity-versus-time graph.

1-47 Plot the position-versus-time graph corresponding to Fig. 1.17. (Assume the object starts from $x = 0$.)

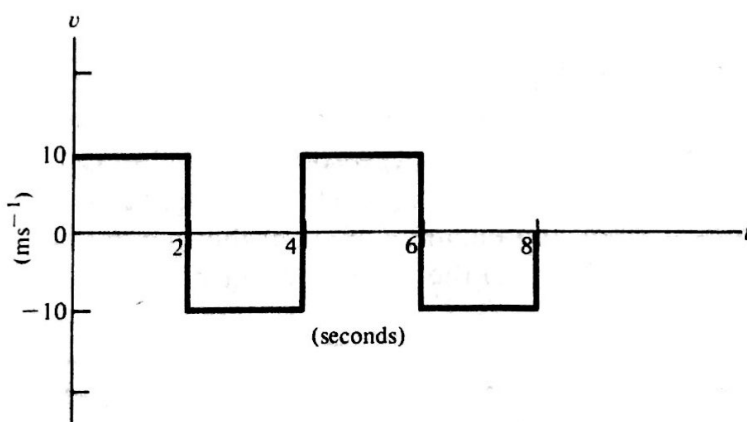


Figure 1.17. Exercise 1-47.

1-48 Suppose a car can accelerate at 1 m s^{-2} . How large a break in traffic is needed to enter a highway where cars are moving at 20 m s^{-1} if the driver wants to avoid forcing the next car to slow down or to approach closer than 25 m?

1-49 A car moving at 15 m s^{-1} hits a stone wall. (a) A seat-belted passenger comes to rest in 1 m. What average acceleration does this person experience? (b) Another passenger without a seat belt strikes the windshield and comes to rest in 0.01 m. What average acceleration does this person experience?

1-50 A racing car initially at rest has a constant acceleration for 0.5 km. Its speed at the end of this period is 100 m s^{-1} . (a) What is the acceleration of the car? (b) How long does it require to cover the 0.5-km distance?

1-51 A baseball pitcher throws a ball at 40 m s^{-1} . If the acceleration is approximately constant over a distance of 2 m, how large is it?

1-52 A baseball player catches a ball moving at 30 m s^{-1} . (a) If he does not move his hand, the ball comes to rest in his glove over a distance of 1 cm. What is the average acceleration? (b) If he moves his hand as the ball is caught so that it comes to rest over 10 cm, what is the acceleration?

Section 1.6 | The Acceleration of Gravity and Falling Objects

1-53 From what height must water fall to strike a turbine wheel with a vertical downward velocity of 30 m s^{-1} ?

1-54 An anti-aircraft shell is fired vertically upward with an initial velocity of 500 m s^{-1} . (a) Compute the maximum height of the shell. (b) How long does it take to reach this height? (c) When will the height be 1000 m?

1-55 A model rocket is fired straight up from ground level with a constant acceleration of 50 m s^{-2} until the engine runs out of fuel after 4 s. Neglecting air resistance, find (a) the height of the rocket when the engine stops; (b) the maximum height reached; (c) the total time duration of the flight.

1-56 A rock falls from a cliff 60 m high. (a) Find the average velocity during the first 3 s of its fall. (b) At what instant of time is the instantaneous velocity equal to the average velocity of part (a)?

(c) How long does it take for the rock to fall to the ground?

1-57 A boy standing beside a tall building throws a ball straight up with an initial velocity of 15 m s^{-1} . (a) How high will the ball rise? (b) How long will it take for the ball to reach its maximum height? (c) Another boy reaches out of a window 6 m above the initial position of the ball and attempts to catch the ball. At what times will the ball pass him?

1-58 A rock dropped from the top of a tower strikes the ground in 4 s. (a) Find the velocity of the rock just before it strikes the ground. (b) Find the height of the tower.

1-59 A stone is thrown vertically downward from a bridge with an initial velocity of 10 m s^{-1} . It strikes the water in 3 s. (a) What is the velocity of the stone as it strikes the water? (b) What is the height of the bridge above the water?

1-60 A stone dropped from a bridge strikes the water in 5 s. (a) What is the velocity of the stone when it strikes the water? (b) What is the height of the bridge?

1-61 The hammer of a pile driver strikes the top of a pipe with a velocity of 7 m s^{-1} . From what height did the hammer fall?

1-62 A sandbag dropped from a balloon strikes the ground in 15 s. What was the height of the balloon if it was initially (a) at rest in the air; (b) descending with a velocity of 20 m s^{-1} ?

1-63 A box falls from an elevator that is ascending with a velocity of 2 m s^{-1} . It strikes the bottom of the elevator shaft in 3 s. (a) How long will it take the box to reach its maximum height? (b) How far from the bottom of the shaft was the box when it fell off the elevator? (c) What is the height of the elevator when the box is at its highest point?

1-64 Repeat Example 1-20 with the $+x$ direction downward.

1-65 Repeat Example 1-21 with the $+x$ direction downward.

1-66 A car moving at 30 m s^{-1} (108 km h^{-1}) collides head on with a stone wall. From what height would the car have to fall to achieve the same results?

1-67 One ball is thrown straight up from a bridge, and another is thrown straight down. Just

before they hit the water, which has the larger acceleration? (Neglect air resistance.)

1-68 In 1971 Apollo 15 astronaut David Scott dropped a hammer and a feather on the moon. The feather fell a distance of 0.73 m in the first second. (a) Did the hammer fall a larger or smaller distance in that second? Explain. (b) What is the acceleration due to gravity on the moon?

1-69 A physics student measures her reaction time by having a friend drop a metre stick between her fingers. The metre stick falls 0.3 m before she catches it. (a) What is her reaction time? (b) Estimate the minimum average speed of nerve impulses going from her eye to her brain and then back to her hand.

1-70 A ball is thrown straight up with an initial velocity of 30 m s^{-1} . (a) How far will it travel in the first second after it is released? (b) What is its velocity after 1 s? (c) What is its acceleration after 1 s?

PROBLEMS

The occasional problems preceded by an asterisk are the most difficult. Answers to most of the odd-numbered problems are given in the back of the book. Solutions to half the odd-numbered problems appear in the Study Guide.

1-71 Figure 1.18 shows the position-versus-time graph for an object. Consider the intervals from 0 to T_1 , T_1 to T_2 , and so on. (a) During which time interval is the object at rest? (b) During which time interval is it moving with constant velocity? (c) During which time interval does it have a positive velocity? (d) During which time interval does

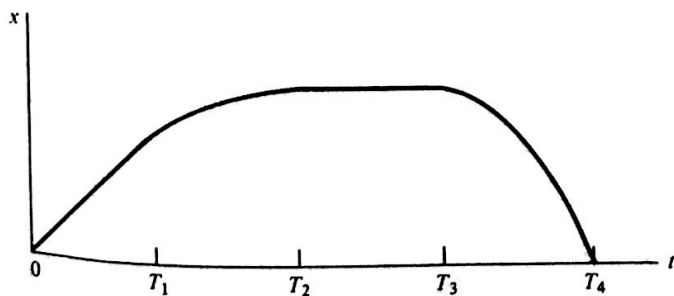


Figure 1.18. Problem 1-71.

it have a negative velocity? (e) During which time interval does it have a positive acceleration? (f) During which time interval does it have a negative acceleration?

1-72 A car traveling at 20 m s^{-1} hits a stone wall. The driver, who is wearing a shoulder harness and seat belt, moves forward 1.0 m as the car stops. Assuming her acceleration is uniform, find (a) her average velocity during the collision; (b) her acceleration.

1-73 We saw that when you throw an object upward, in the absence of air resistance, it takes as long for the object to come down again as to reach its highest point. Are these times equal when there is air resistance? Explain.

1-74 Galileo concluded that falling objects have a constant acceleration because their distance varies with the square of the elapsed time: $x = ct^2$. Is this equation valid when air resistance is present? If not, explain qualitatively how the equation would have to be modified.

1-75 At the instant a bowler releases the ball, her hand is moving horizontally with a speed of 6 m s^{-1} relative to her body. If she is moving forward at a speed of 1 m s^{-1} , what is the velocity of the ball with respect to the floor?

1-76 When a bowling ball is released, a bowler's hand is moving relative to his forearm at 0.82 m s^{-1} . The forearm is moving relative to the upper arm at 0.55 m s^{-1} , and the upper arm is moving at 5.26 m s^{-1} relative to the shoulder. (The velocities refer to the outermost ends of the respective parts of the body and are all horizontal.) If the bowler's shoulder is moving relative to the floor at 1.43 m s^{-1} , how fast is the ball thrown?

1-77 A girl rows 12 km downstream in 2 h. Her return trip takes 3 h. (a) How fast can she row in still water? (b) How fast is the current?

1-78 A boy is on a train moving at 70 km h^{-1} . Relative to the ground, how fast is he moving if he runs at 15 km h^{-1} (a) toward the front of the train; (b) toward the rear?

1-79 The position-versus-time graph for a pendulum is shown in Fig. 1.14. Sketch the velocity-

versus-time and acceleration-versus-time graphs for the motion.

1-80 A sled starting from rest slides down a hill with uniform acceleration. It travels 12 m in the first 4 s. When will the sled have a velocity of 4 m s^{-1} ?

1-81 A racing car initially at rest accelerates for one-quarter of a kilometre and then brakes to a stop in an additional one-half kilometre. (a) Sketch an approximate velocity-versus-time graph. (b) Sketch an acceleration-versus-time graph.

1-82 Plane A, flying at 500 m s^{-1} , is 10,000 m directly behind plane B, moving in the same direction at 400 m s^{-1} . The pilot of plane A fires a missile that accelerates at 100 m s^{-2} . How long will it take for the missile to reach plane B? (Neglect the effects of the gravitational acceleration.)

1-83 A dog running at 10 m s^{-1} is 30 m behind a rabbit moving at 5 m s^{-1} . When will the dog catch up with the rabbit? (Both velocities remain constant.)

1-84 A rocket-powered experimental sled carrying a test pilot is brought to rest from 200 m s^{-1} over a distance d . If the pilot is not to be subjected to an acceleration greater than six times that of gravity, what is the minimum value of d ?

***1-85** The world record for the 100-m dash is 9.95 s and for the 60-m dash, it is 6.45 s. Assume a sprinter accelerates at a constant rate up to a maximum velocity that is maintained for the remainder of the race, no matter how long it is. (a) Find the acceleration. (b) What is the duration of the acceleration period? (c) What is the maximum velocity? (d) The record for the 200-m dash is 19.83 s, while for the 1000-m run it is about 133.9 s. Are these times consistent with the assumptions made?

1-86 A sandbag is dropped from an ascending balloon that is 300 m above the ground and is ascending at 10 m s^{-1} . (a) What is the maximum height of the sandbag? (b) Find the position and velocity of the sandbag after 5 s. (c) How long does it take for the sandbag to reach the ground from the time it was dropped?

***1-87** In the television show "The Six Million Dollar Man," Colonel Austin had superhuman capabilities. In one episode he tries to catch a man fleeing in a sports car. The distance between them is 100 m when the car begins to accelerate with a constant acceleration of 5 m s^{-2} . Colonel Austin runs at a constant speed of 30 m s^{-1} . Show that he cannot catch the car, and find his distance of closest approach.

1-88 In Fig. 1.8b, the shaded area has a triangular portion (above the v_0 line) and a rectangular portion. Show that the sum of their areas reduces to the right-hand side of Eq. 1.8.

1-89 (a) A magazine article states that cheetahs are the fastest sprinters in the animal world and that a cheetah was observed to accelerate from rest to 70 km h^{-1} in 2 s. What average acceleration in m s^{-2} does this require? (b) The article also says the cheetah covered 60 m during that 2-s interval. How large a constant acceleration is implied by this statement? Does it agree with your result in (a)? (c) Accelerations substantially greater than g are difficult for an animal or an automobile to attain, because there is a tendency to slip even on very rough ground with larger acceleration. Given this information, can you guess which number is wrong in the article?

1-90 A rock is dropped into a well and a splash is heard 3 s later. If sound travels in air at 344 m s^{-1} , how deep is the well?

1-91 A lightning flash is seen, and 5 s later thunder is heard. Assuming they are produced simultaneously, how far away is the flash? (In air, sound travels at 344 m s^{-1} and light at $3.00 \times 10^8 \text{ m s}^{-1}$.)

1-92 An estimate of the difficulties involved in space exploration beyond the solar system can be seen from the following calculation. (a) The distance to the moon from the earth is $3.84 \times 10^8 \text{ m}$. Present-day spaceships require about 24 hours to reach the moon. What is the average velocity of these spaceships? (b) The nearest star to our solar system is about 4 light-years away, where a light-year is the distance traveled by light in 1 year (365 days) and the speed of light is $3.00 \times 10^8 \text{ m s}^{-1}$. How many years would it take to reach this star if the spaceship had the velocity calculated in (a)?