The speed of light is a million times faster than sound. Just the fact that you can hear the thunder means the lightning occurred fairly close by.]

34. [II] A test explosion occurs at ($t = 0$) while you are in a distant bunker. The instruments in the bunker record the flash 0.02 ms later. Roughly when will you experience the shock wave, which travels at a constant 3×10^2 m/s? Draw a diagram.

35. [II] While the Apollo astronauts were on the Moon, 3.844×10^8 m away, they communicated using radio-waves, which travel at the speed of light. The Earth's atmosphere, which is about 160-km thick, affects the speed of the signal by less than 0.1 percent. About how long will the ground controller have to wait from the end of a question to the start of an answer, given that an astronaut takes 1 s to begin to respond?

36. [II] Figure P27 is a plot of the speed of a cat versus time. Approximately, what was its instantaneous speed at each of the following times, 0, 1.0 s, 2.0 s, 4.5 s, 6.0 s, and 7.0 s? During what time intervals was its speed increasing? When was its speed decreasing?

37. [II] While driving in a car along a winding mountain road a passenger makes a plot of the tripmeter's readings against time. Placing a dot on the distance versus time curve every 10.0 s for 5 min he gets a straight line passing through the $l = 0$, $t = 0$ origin and having a slope of 16.0 m/s. (a) What is the instantaneous speed of the car 45 s into the exercise? (b) How far does the car travel in the time between $t = 86$ s and $t = 186$ s?

SOLUTION: (a) The slope of the curve is the speed and it's constant at 16.0 m/s = $v_{av} = \Delta l/\Delta t$. (b) We need the distance, $\Delta l = v_{av}\,\Delta t$ and therefore the time interval, $\Delta t = 186\text{ s} - 86\text{ s} = 100$ s. $\Delta l = v_{av}\,\Delta t = (16.0\text{ m/s})(100\text{ s}) = 16.0 \times 10^2$ m.

38. [III] If the equation describing the motion of a rocket in SI units is $l = 10 + 5t^2$, find its average speed during the first 5.0 s of flight. [*Hint: At a time* $(t + \Delta t)$, *the object is at* $(l + \Delta l)$.] Write an expression for the instantaneous speed of the rocket [see Eq. (2.4)].

39. [III] Given the equation describing the motion of a falling object $l = Ct^2$ (where C is a constant), show that its average speed during the interval from t to $(t + \Delta t)$ is

$$v_{av} = 2Ct + C\Delta t$$

[*Hint: At a time* $(t + \Delta t)$, *the object is at* $(l + \Delta l)$.] Now determine an equation for the instantaneous speed from Eq. (2.4).

SECTION 2.5: THE DISPLACEMENT VECTOR

SECTION 2.6: SOME VECTOR ALGEBRA

40. [I] A mouse runs straight north 1.414 m, stops, turns right through 90°, and runs another 1.414 m due east. Through what distance is it displaced? Draw a diagram.

41. [I] A green frog with a body temperature of 18 °C at rest at the edge of a 1.0-m-high table jumps off perpendicularly and lands on the ground 1.0 m out from the edge. Determine the length of its displacement vector. Draw a diagram.

42. [I] A youngster on the roof of a 19.0-m-tall building stands at the edge and throws a paper plane from a height of 1.00 m above the roof. It sails around before landing directly in front of him 15.0 m from the building. What is the magnitude of the displacement of the plane from its launch point? Draw a diagram.

43. [I] A robot on the planet Mongo leaves its storage closet and heads due east for 9.0 km. It then turns south for 12 km and stops. Neglecting the curvature of the planet, what is the magnitude of the robot's displacement? Draw a diagram. [*Hint: We need to determine the sum of two displacement vectors. The resulting triangle has sides of 9 km and 12 km; that suggests a 3-4-5 right triangle.*]

44. [I] After lifting off its launchpad, a rocket is found to be 480 m directly above an observer who is 360 m due east of the pad. What is the displacement of the rocket from the pad at that moment? Draw a diagram.

45. [I] While meandering on a blanket on the grass at a picnic, an ant takes 603 steps north from a cookie crumb. It then walks 804 steps due west and stops at a raisin. What is the displacement of the ant from the crumb? Give your answer in ant-steps and provide the direction. Draw a diagram.

46. [I] A jogger in the city runs 4 blocks north, 2 blocks east, 1 block south, 4 blocks west, 1 block north, 1 block east, and collapses. Determine the magnitude of the jogger's displacement. Draw a diagram.

47. [I] A stationary wooden horse on a merry-go-round is carried along a 31.4-m circumference each time the machine turns once around. Determine the magnitude of the horse's displacement for half a turn. Draw a diagram.

48. [I] Practicing golf at the Grand Canyon, someone taps a ball that rolls in a long arc coming to the edge of a cliff. The point the ball reaches at the edge is a straight 20.0 m away at the same elevation as the tee from which it was hit. The ball drops over the edge, falling into a bird's nest on a ledge 32.0 m down. Determine the magnitude of the displacement of the ball from the tee. Draw a diagram.

SOLUTION: The displacement from the tee is the hypotenuse of the right triangle formed by the two displacements of 20.0 m and 32.0 m. Thus $s = \sqrt{(20.0\text{m})^2 + (32.0\text{m})^2} = 37.7$ m.

49. [I] THIS PROBLEM WILL HELP US BETTER UNDERSTAND THE NOTION OF DISPLACEMENT. G3, a maintenance android, leaves his closet and heads due east for 15.5 m. He stops for 310 s to make a repair, and then travels 22.1 m east to get a tool. He then wheels around 180° and walks 7.6 m west, at which point he determines the magnitude of his displacement from his closet. (a) Draw a diagram showing each displacement vector sequentially placed tail-to-tip. (b) What is the significance of the vector drawn from the first tail to the last tip? (c) What is the magnitude of his displacement?

50. [I] THIS PROBLEM WILL HELP US BETTER UNDERSTAND THE DIFFERENCE BETWEEN DISTANCE AND DISPLACEMENT. Someone holding a ball out of a window 20.0 m above ground drops it. The ball hits the sidewalk and on its first bounce climbs 10.0 m straight up. (a) What was the ball's displacement from the person's hand at the moment it struck the ground? (b) What was its displacement from the hand after it rose 10.0 m? (c) How far had it traveled up until that moment?

51. [I] A boy scout troop marches 10 km east, 5.0 km south, 4.0 km west, 3.0 km south, 6.0 km west, and 8.0 km north. What is their net displacement from their starting point? How far have they marched? Draw a diagram.

52. [I] A marble, on the first shot of a tournament game in 1942 in Brooklyn, was displaced by $\vec{s}$ equal to 3.0 m in a direction 60° N of E. On the next shot, it was displaced from its new location by an amount $-4.0\,\vec{s}$. Where did it end up? Draw a diagram.