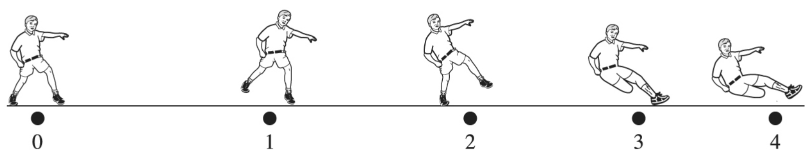
# 1

# REPRESENTING MOTION

**Q1.1. Reason:** The softball player starts with an initial velocity but as he slides he moves slower and slower until coming to rest at the base. The distance he travels in successive times will become smaller and smaller until he comes to a stop. See the figure below.

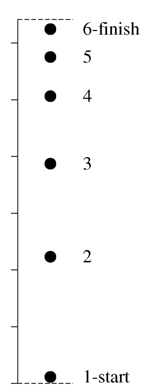



**Assess:** Compare to Figure 1.10 in the text.

**Q1.2. Reason:**

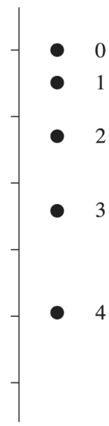

**Assess:** The dots are equally spaced until the brakes are applied to the car. Equidistant dots indicate constant average speed. On braking, the dots get closer as the average speed decreases.

**Q1.3. Reason:**



**Assess:** The spacing between dots is initially large, since the initial speed with which the bush baby leaves the ground is large. As the bush baby rises and gravity slows the ascent, the speed decreases and therefore the spacing between adjacent dots in the motion diagram decreases.

**Q1.4. Reason:** As the ball drops from the tall building t02.he ball will go faster and faster the farther it falls under the pull of gravity. The motion diagram should show the displacements for later times to be getting larger and larger. The successive displacements in the diagram given in the text get smaller and smaller. So the diagram given in the problem is incorrect. The correct diagram is below.




**Assess:** Compare to Figure 1.5 in the text, which shows a motion diagram for two objects falling under the influence of gravity. The displacements increase during the fall of the object as we reasoned.

**Q1.5. Reason:** Position refers to a location in a coordinate frame. A displacement is the difference between two positions. In general, displacement is a vector and requires a direction. But in this one-dimensional case, we ignore that subtlety. The four miles Mark and Sofia walked definitely refer to a difference between their starting and ending positions. There is no information given about a reference frame. So it is more reasonable to associate the four miles with a displacement (magnitude) than with an absolute position.
**Assess:** Mark and Sofia's position could be specified as (for example) 100 m west of a particular intersection. But what is described is a difference between two positions. This is more like a displacement magnitude. Note that if their starting point had been the origin of a coordinate system, then both Mark and Sofia would be correct.

**Q1.6. Reason:** The distance you travel will be recorded on the odometer. As you travel, the distance you travel accumulates, is recorded by the odometer, and is independent of the direction of travel. Your displacement is the difference between your final position and your initial position. If you travel around a 440 m track and end up where you started, you have traveled 440 m; however, since you ended up where you started, your change in position and hence displacement is zero.
**Assess:** If you watch a track meet, you will observe the 440-m race. As you watch the race, it is obvious that the runners travel a distance of 440 m (assuming they complete the race). Yet since they end up where they started, their final position is the same as their initial position and hence their displacement is zero.

**Q1.7. Reason:** Both speed and velocity are ratios with a time interval in the denominator, but speed is a scalar because it is the ratio of the scalar distance over the time interval while velocity is a vector because it is the ratio of the vector displacement over the time interval. Speed and velocity have the same SI units, but one must specify the direction when giving a velocity.
An example of speed would be that your hair grows (the end of a strand of hair moves relative to your scalp) at a speed of about 0.75 in/month.
An example of velocity (where direction matters) would be when you spring off a diving board. Your velocity could initially be 2.0 m/s up, while later it could be 2.0 m/s down.

**Assess:** Saying that a velocity has both magnitude and direction does not mean that velocity is somehow "better" and that speeds are never useful. Sometimes the direction is unimportant and the concept of speed is useful. In other cases, the direction is important to the physics, and velocity should be cited. Each shows up in various physics equations.

**Q1.8. Reason:** Since the velocity of the skateboard is negative during the whole time of its motion, it is moving in the negative direction the entire 5 seconds. In order to move closer to the origin, which is in the positive direction relative to the starting point of the skateboard, the skateboard must have had a velocity in the positive direction for some time. Since the velocity is always negative, the skateboard must be farther from the origin than initially.
**Assess:** Velocity gives direction of motion since it refers to displacements and not only distance traveled. If velocity is always negative, displacement will be negative also.

**Q1.9. Reason:** If the position of the bicycle is negative it is to your left. The bicycle's velocity is positive, or to the right, so the bicycle is getting closer to you.
**Assess:** If the initial position had been positive and the velocity positive, the bicycle would be getting farther away from you.

**Q1.10. Reason:** Since the jogger is running around a track, she returns to her starting point at the end of the lap. Since her final position is the same as her initial position, her displacement is 0 m. Velocity is defined as

$$\text{velocity} = \frac{\text{displacement in a given time interval}}{\text{time interval}}$$

So her average velocity is 0 m/s!
However, though her displacement is 0 m, the actual distance she traveled is 400 m. Her average speed is not zero, since speed is defined in terms of distance, not displacement.

$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}}$$

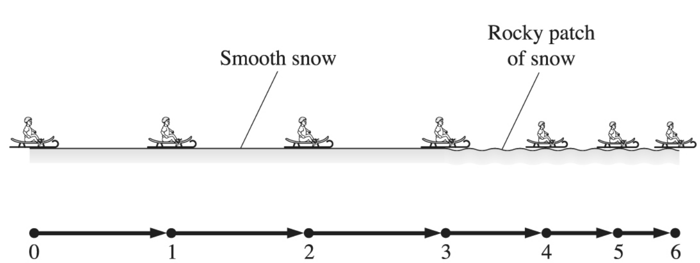
Her average speed is then $\frac{400\text{ m}}{100\text{ s}} = 4\text{ m/s}$.

The second friend is correct.
Since the motion of a runner is not uniform we can only calculate average velocity and average speed.
**Assess:** This problem illustrates a very important difference between speed and velocity. Speed depends on total distance traveled. Velocity depends on displacement, which only takes into account the starting and ending points of a motion.

**Q1.11. Reason:**

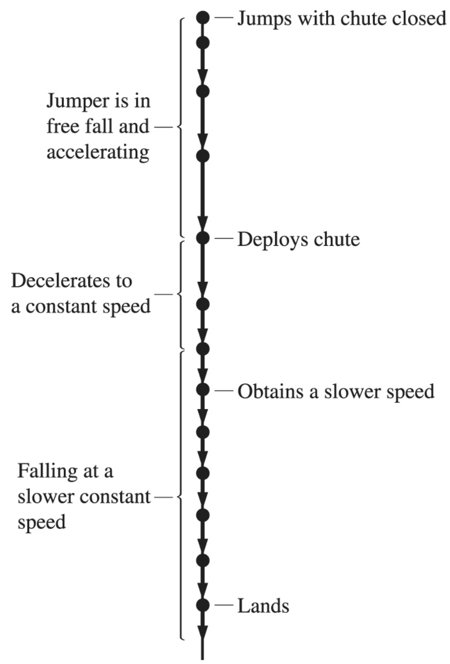

**Assess:** The dots get farther apart and the velocity arrows get longer as she speeds up.

**Q1.12. Reason:** The child will be traveling with a constant velocity until hitting the rocky patch. During the constant velocity part of the motion the motion diagram should show equal displacements during each time interval. After hitting the rocky patch, the sled will start slowing. After this point the motion diagram should show ever-decreasing displacements and ever-decreasing velocity vectors. The motion diagram is below.



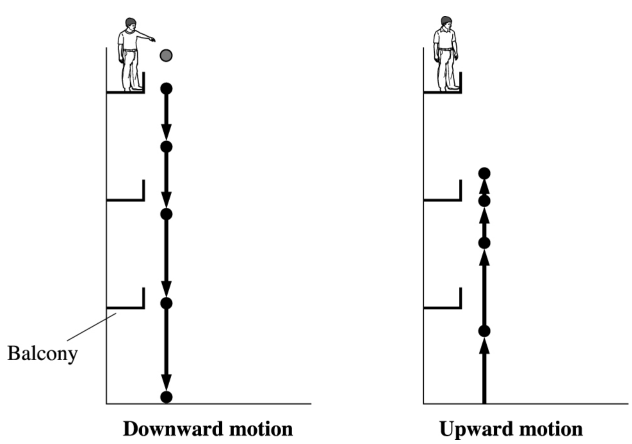

**Assess:** Compare to Figure 1.11 in the text where a similar motion is illustrated.

**Q1.13. Reason:** The initial velocity is zero. The velocity increases and the space between position markers increases until the chute is deployed. Once the chute is deployed, the velocity decreases and the spacing between the position markers decreases until a constant velocity is obtained. Once a constant velocity is obtained, the position markers are evenly spaced. See the following figure.



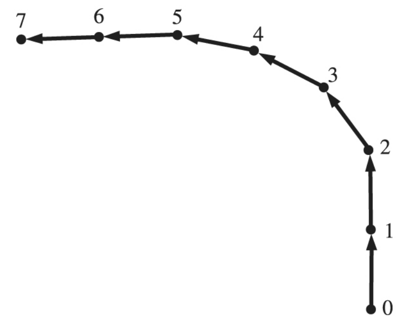

**Assess:** Knowing the velocity of the jumper will increase until the chute is deployed and then rapidly decrease until a constant descent velocity is obtained allows one to conclude that the figure is correct.

**Q1.14. Reason:** The tennis ball falls freely for the three stories under the pull of gravity. Since gravity is pulling it downward, its speed increases with time. It strikes the ground and very quickly slows down to a stop (while compressing the ball) then bounces back upward (while the ball decompresses). After the bounce, it travels upward while still under the pull of gravity. As it is traveling upward the pull of gravity decreases its velocity to zero at a height of two stories. The downward and upward motions of the ball are shown in the figure below. The increasing length of the arrows during the downward motion indicates increasing velocity. The decreasing length of the arrows during the upward motion indicates the particle slowing down.



**Assess:** Compare Figure 1.5 in the text for the downward motion. Note that gravity always pulls downward, no matter what the direction of motion of something under its influence. So the ball will constantly be slowing down during its upward motion.

**Q1.15. Reason:**




**Assess:** The car (particle) moves at a constant speed $v$ so the distance between the dots is constant. While turning $v$ remains constant, but the direction of $\vec{v}$ changes.

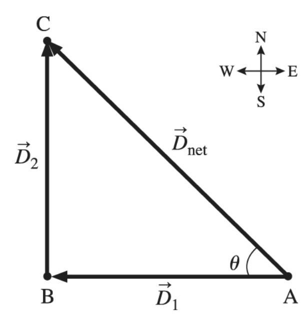
**Q1.16. Reason:** No. The 4 m vector is longer than the other two combined. The 1 m and 2 m vector cannot undo the 4 m vector.
**Assess:** This is easy to see if we think of these vectors as displacement vectors. If a person moves 4 m in a straight line, it is obvious that they cannot return to their starting point by moving only 1 m and then 2 m in any direction.

**Q1.17. Reason:** We do not believe Travis. 55 m is more than 165 ft. It is not reasonable to think that a unicycle could move that quickly.
**Assess:** The evaluation may be easier in different units. Consider converting to miles per hour:

$$\frac{55\text{ m}}{\text{s}} \times \frac{1\text{ mi}}{1610\text{ m}} \times \frac{3600\text{ s}}{1\text{ hr}} = 120\text{ mph}$$

This is twice the speed limit on many freeways, and not reasonable for a unicycle.

**Q1.18. Reason:** The student changes direction during the walk. Her first displacement vector is 1.0 m west, and her second is in a different direction, 1.0 mi north. We need to use the rules for addition of vectors to find the distance she is from her starting point. The distance is the length of her net displacement vector. See the diagram below.




Her displacement is $\vec{D}_{\text{net}} = \vec{D}_1 + \vec{D}_2$. The length of $\vec{D}_{\text{net}}$ is given by the Pythagorean theorem since the displacement vectors form a right triangle. Her net displacement vector is along the hypotenuse of the triangle.

$$\overline{AC} = \sqrt{\overline{AB}^2 + \overline{BC}^2} = \sqrt{(1.0\text{ mi})^2 + (1.0\text{ mi})^2} = 1.4\text{ mi}$$

We can find her direction also, though this is not asked for in this question. The angle would be given by

$$\theta = \arctan\left(\frac{1.0 \text{ mi}}{1.0 \text{ mi}}\right) = \arctan(1.0) = 45°$$

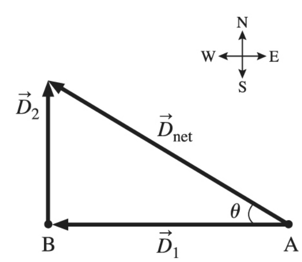
So the student's displacement is 1.4 mi 45° north of west.
The correct answer is B.
**Assess:** To find a net displacement the laws of vector addition must be used. The net displacement here is the vector addition of the displacements that made up the motion.

**Q1.19. Reason:** Since the rock is above the origin the position is positive; since it is still moving upward the velocity is also positive. Hence, the correct answer is A.
**Assess:** After it gets to the top and starts back down, the position will still be positive, but the velocity will be negative.

**Q1.20. Reason:** Because of the numbering of the dots, we see the object is moving to the left. It is slowing because the dots are getting closer together. The choice that fits this scenario is a cyclist moving to the left and braking to a stop. So choice B is correct.
**Assess:** If the dots were numbered in reverse order then choice C would be correct.

**Q1.21. Reason:** Because the dots are getting farther apart to the right (and the numbers are increasing to the right) we know that the object is speeding up. The choice that best fits that is a car pulling away (to the right) from a stop sign. So the correct choice is C.
**Assess:** An ice skater gliding (choice A) would likely have nearly constant velocity (constant spacing between dots). The motion diagram for a plane braking (choice B) might look like the given diagram with the dots numbered in reverse order. The pool ball reversing direction (choice D) would have dot numbers increasing in one direction at first but then going the other way.

**Q1.22. Reason:** The bird changes direction during the flight. The first displacement vector is 3.0 km due west, and her second is in a different direction, 2.0 km due north. We can use the rules for addition of vectors to find the distance the bird is from her starting point. The distance is the length of her net displacement vector. See the diagram below.




The bird's net displacement is $\vec{D}_{net} = \vec{D}_1 + \vec{D}_2$. The length of $\vec{D}_{net}$ is given by the Pythagorean theorem since the displacement vectors form a right triangle. The net displacement vector is along the hypotenuse of the triangle.

$$\overline{AC} = \sqrt{\overline{AB}^2 + \overline{BC}^2} = \sqrt{(3.0 \text{ km})^2 + (2.0 \text{ km})^2} = 3.6 \text{ km}$$

We can find the direction of the displacement also, though this is not asked for in this problem. In general, to specify a displacement a length and a direction must be specified. The angle in the diagram would be given by

$$\theta = \arctan\left(\frac{2.0 \text{km}}{3.0 \text{km}}\right) = 34°$$

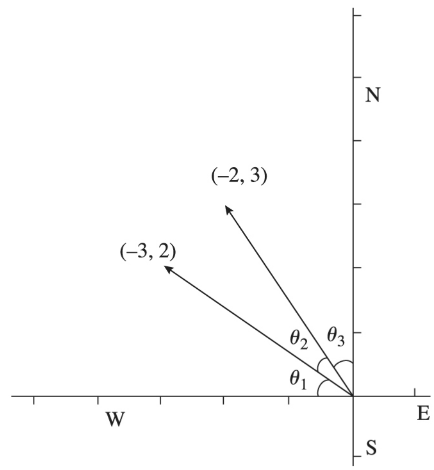
So the bird's displacement is 3.6 km 34° north of west.
The correct answer is C.
**Assess:** The net displacement is made up of the vector addition of the displacements that made up the motion.

**Q1.23. Reason:** The speed is the distance divided by the time.

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{0.30\text{ km}}{5.0\text{ min}}\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 1.0\text{ m/s}$$

So the correct choice is B.
**Assess:** 1 m/s does seem like a reasonable speed for a seal in water.

**Q1.24. Reason:**




$\theta_1 = \theta_3$ and either of them can be deduced from $\tan^{-1}\left(\frac{2}{3}\right) = 33.7°$.

$$\theta_2 = 90° - 2(\theta_1) = 90° - 2(33.7°) = 23°$$

So the correct choice is A.
**Assess:** By a quick back-of-the-envelope sketch we can see that choices C and D are much too large.

**Q1.25. Reason:** This is a simple unit conversion problem:

$$\frac{400\text{ m}}{51.9\text{ s}} \times \frac{1\text{ mi}}{1610\text{ m}} \times \frac{3600\text{ s}}{1\text{ hr}} = 17.2\text{ mph}$$

So the correct choice is C.
**Assess:** This is the speed of a slow-moving car, and is reasonable for a very fast-moving human.

**Q1.26. Reason:** The second rule on significant figures says that when adding two numbers the number of decimal places in the answer should match the *smallest* number of decimal places of any number used in the calculation. There are three decimal places in 0.532 m, but only two in 3.24 m, so our answer must have only two decimal places. Therefore the correct choice is B: 3.77 m.
**Assess:** On contemplation we realize that we don't know the 3.24 m number better than to the nearest cm, and that will also be true of the answer, even though we may know the other number to the nearest millimeter.

**Q1.27. Reason:** When multiplying numbers, the correct number of significant digits is the smaller of the numbers of significant digits in the two numbers. That is, here we have four significant figures in 109.7 m and three in 48.8 m, and so our product must have three significant digits:

$$(109.7\text{ m}) \times (48.8\text{ m}) = 5.35 \times 10^3\text{ m}^2$$

The correct answer is B.
**Assess:** Our final answer has three digits of precision, since we multiplied by something with only three digits of precision.

**Q1.28. Reason:** This is a straightforward unit conversion question.

$$4.57\times10^9 \text{ years} = 4.57\times10^9 \text{ yr}\left(\frac{365.25 \text{ d}}{1 \text{ yr}}\right)\left(\frac{24 \text{ h}}{1 \text{ d}}\right)\left(\frac{60 \text{ min}}{1 \text{ h}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = 1.44\times10^{17} \text{ s}$$

The correct choice is D.
**Assess:** Notice that even though we have more significant figures in some of the conversion factors (we accounted for leap year, and the other factors are exact and have as many significant figures as we need) that we obey the significant figure rules and report the answer to the same number of significant figures as the number of significant figures in the least precisely known number in the calculation (the age in years).

**Q1.29. Reason:** We are given an equation for density and are asked to calculate the density of the earth given its mass and volume. However, the units must be converted before the calculation is done since we're given volume in $\text{km}^3$ and the answer must be given in terms of $\text{m}^3$.

$$\begin{aligned} V &= (1.08\times10^{12} \text{ km}^3)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right) \\ &= (1.08\times10^{12} \text{ km}^3)\left(\frac{10^3 \text{ m}}{1 \text{ km}}\right)^3 = (1.08\times10^{12} \text{ km}^3)\left(\frac{10^9 \text{ m}^3}{1 \text{ km}^3}\right) \\ &= 1.08\times10^{21} \text{ m}^3 \end{aligned}$$

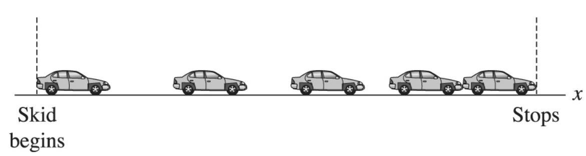
Note carefully that we needed *three* conversion factors for the conversion from km to m here since we are dealing with cubic kilometers. Three factors are needed to cancel the factor of $\text{km}^3 = \text{km}\cdot\text{km}\cdot\text{km}$.
So the density is

$$\rho = \frac{M}{V} = \frac{5.94\times10^{24} \text{ kg}}{1.08\times10^{21} \text{ m}^3} = 5.50\times10^3 \text{ kg/m}^3$$

The correct choice is A.
**Assess:** For cubic and square units (or units to any power) you must include the correct number of conversion factors to convert every factor in the original quantity. Since the density of water is $1.0\times10^3 \text{ kg/m}^3$, it seems reasonable that the earth would be 5.5 times as dense.

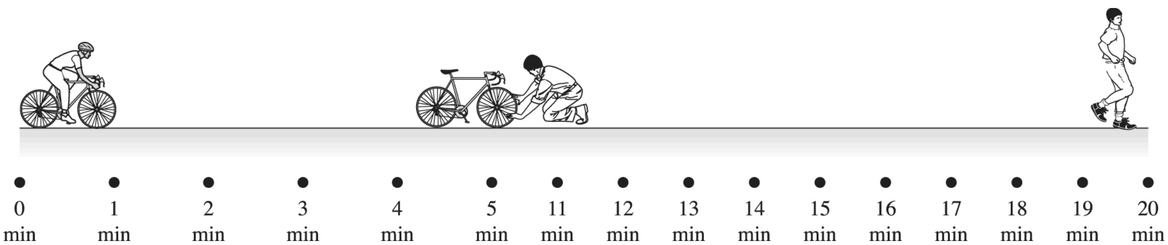
## Problems

**P1.1. Strategize:** A motion diagram consists of images or positions of an object shown with equal time intervals between each successive image. This is similar to images taken by a camera with fixed timing between images.
**Prepare:** Frames of the video are taken at equal intervals of time. As a result, we have a record of the position of the car at successive time equal intervals – this information allows us to construct a motion diagram.
**Solve:**



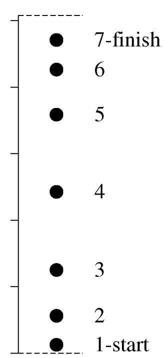

**Assess:** Once the brakes are applied, the car slows down and travels a smaller distance during each successive time interval until it stops. This is what the car in the figure is doing.

**P1.2. Strategize:** For a motion diagram we want to make dots indicating the person's position, one for each fixed time interval. In this case, the natural time interval to use is one minute.
**Prepare:** We will assume the man travels with constant speed while he's walking and riding. There are three parts to motion, each with constant speed.
**Solve:** The diagram is below.



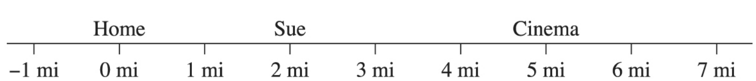

**Assess:** While the man is walking his speed is less than when riding the bicycle, so the dots should be more closely spaced during that part of the trip.

**P1.3. Strategize:** To draw an accurate motion diagram, we must consider when Amanda speeds up and when she slows down, and we must space the dots in our diagram accordingly.
**Prepare:** As the elevator begins to rise, its speed changes from zero to some other speed. An elevator typically maintains a steady speed for a while, and then slows as it reaches the desired floor. So our diagram should start with very small but increasing spacing between dots (getting started), then have wider spaced dots with constant spacing for some time (constant speed), and finally dots with decreasing spacing (slowing to a stop).
**Solve:**

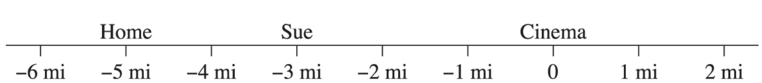



**Assess:** The speed (and therefore the spacing between dots) increases from 1 to 3, then stays constant from 3 to 5, and decreases from 5 to 7.

**P1.4. Strategize:** We are asked to find a displacement, which does not depend on the origin. Therefore, we expect to find the same answer to parts (a) and (b).
**Prepare:** We must determine Sue's position, being careful of the sign of the displacement.
**Solve: (a)** Refer to the figure below.




If Sue's home is the origin of the $x$-axis, she is 2 mi to the right of the origin. This is the positive side of the axis, so her position $x = +2$ mi.
**(b)** Refer to the figure below.



Taking the cinema as the origin of the $x-$axis, then Sue is 3 mi to the left of the origin. This is the negative portion of the axis, so Sue's position is $x = -3$ mi.
**Assess:** Displacement along a straight line is a *signed* quantity. It's important to indicate the sign when reporting a displacement relative to a chosen origin. See Figures 1.13 and 1.12 in the text for examples of both negative and positive displacements, respectively.

**P1.5. Strategize:** The displacement is the difference between two positions. It does not depend on the origin.
**Prepare:** To find Sue's displacement, we want to find the difference between her initial position between her home and the cinema, and her position at her home.
**Solve:** It is graphically clear that $\Delta x = x_f - x_i = 2$ mi. This is the answer for both parts (a) and (b).
**Assess:** Sue's position depends on where the origin is. But the displacement is the difference between two points (initial and final), and that is independent of what point in space we label as our origin.

**P1.6. Strategize:** The displacement is the difference between the initial and final positions.
**Prepare:** In this case, we know that the initial position is at the 65 mm mark and the final position is at the 42 mm mark. We find the displacement using $\Delta x = x_f - x_i$.
**Solve:** We have $\Delta x = x_f - x_i = (42 \text{ mm}) - (65 \text{ mm}) = -23$ mm.
**Assess:** This is a reasonable distance for a paramecium under a microscope, and since the final position is a smaller number than the initial number, the negative sign of the displacement also makes sense.

**P1.7. Strategize:** Displacement is the difference between a final position $x_f$ and an initial position $x_i$.
**Prepare:** The displacement can be written as $\Delta x = x_f - x_i$, and we are given that $x_i = 23$ m and that $\Delta x = -45$m.
**Solve:** $\Delta x = x_f - x_i$
Since we want to know the final position we solve this for $x_f$.

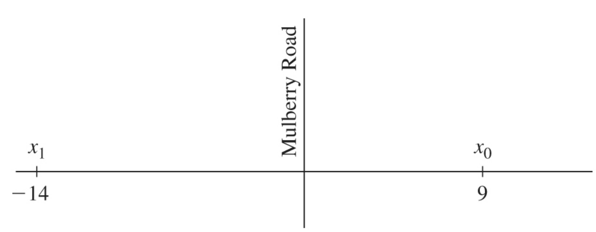
$$\begin{aligned} x_f &= x_i + \Delta x \\ &= 23 \text{ m} + (-45 \text{ m}) \\ &= -22 \text{ m} \end{aligned}$$

**Assess:** A negative displacement means a movement to the left, and Keira has moved left from $x = 23$ m to $x = -22$ m.

**P1.8. Strategize:** Displacement along a straight line is a signed quantity, and is given by $\Delta x = x_f - x_i$.
**Prepare:** Since this problem asks for displacements relative to Mulberry Road, we will choose Mulberry Road as the origin.
**Solve:** Since Mulberry Road was chosen as the origin and $x$ increases to the east, the final position of the car is $x_f = -14$ mi. We are told that the displacement of the car was $\Delta x = -23$ mi, so during its motion the car traveled 23 mi west. We can use the definition of displacement, $\Delta x = x_f - x_i$, to find the car's initial position.

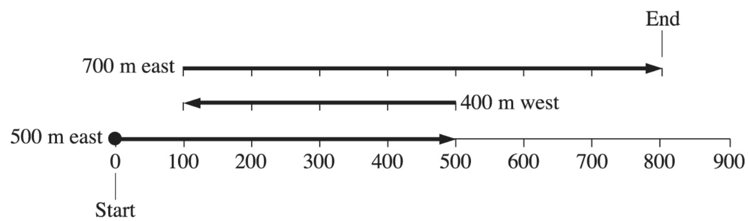
$$x_i = x_f - \Delta x = (-14 \text{ mi}) - (-23 \text{ mi}) = +9 \text{ mi}$$

The car started 9 mi east of Mulberry Road.



**Assess:** Note the choice of origin for measuring positions and displacements is arbitrary, but in many cases it's convenient to choose a reference point in the problem as the origin. Here, all displacements and positions were mentioned relative to Mulberry Road, which was chosen as the origin and made the calculations direct.

**P1.9. Strategize:** We must combine three different displacements to determine the total displacement.
**Prepare:** We have been given three different displacements. The problem is straightforward since all the displacements are along a straight east-west line. All we have to do is add the displacements and see where we end up.
**Solve:** The first displacement is $\Delta\vec{x}_1 = 500\text{ m}$ east, the second is $\Delta\vec{x}_2 = 400\text{ m}$ west and the third displacement is $\Delta\vec{x}_3 = 700\text{ m}$ east. These three displacements are added in the figure below.




From the figure, note that the result of the sum of the three displacements puts the bee 800 m east of its starting point.
**Assess:** Knowing what a displacement is and how to add displacements, we are able to obtain the final position of the bee. Since the bee moved 1200 m to the east and 400 m to the west, it is reasonable that it would end up 800 m to the east of the starting point.

**P1.10. Strategize:** We are told the guard has a steady pace, meaning there is only one speed to calculate (the average speed). This speed is defined in Equation 1.1 of the text.
**Prepare:** Speed is the distance traveled in some time interval divided by the length of the time interval (at least in this case of a steady pace, in which average speed and speed refer to the same thing).
**Solve:** From Equation 1.1,

$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}} = \frac{110\text{ m}}{240\text{ s}} = 0.46\text{ m/s}$$

**Assess:** Someone walking at a brisk pace will easily travel more than 1 m/s. However, since a guard would travel at more like a stroll, this is a reasonable speed.

**P1.11. Strategize:** In all cases, objects are moving at a steady pace. So speed is just the distance divided by the time.
**Prepare:** We are asked to rank in order three different speeds, so we simply compute each one according to Equation 1.1:

$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}}$$

**Solve:** (i) Toy $\quad \dfrac{0.15\text{ m}}{2.5\text{ s}} = 0.060\text{ m/s}$

(ii) Ball $\quad \dfrac{2.3\text{ m}}{0.55\text{ s}} = 4.2\text{ m/s}$

(iii) Bicycle $\quad \dfrac{0.60\text{ m}}{0.075\text{ s}} = 8.0\text{ m/s}$

(iv) Cat $\quad \dfrac{8.0\text{ m}}{2.0\text{ s}} = 4.0\text{ m/s}$

So the order from fastest to slowest is bicycle, ball, cat, and toy car.

**Assess:** We reported all answers to two significant figures as we should according to the significant figure rules. The result is probably what we would have guessed before solving the problem, although the cat and ball are close. These numbers all seem reasonable for the respective objects.

**P1.12. Strategize:** In the motion diagram, we are told the time interval between each pair of dots. The positions have been labeled. Thus we have sufficient information to determine speeds on different time intervals.
**Prepare:** We can use Equation 1.2 to calculate the horse's velocity at the different times.
**Solve:** Since the dots are spaced at equal intervals of time, and there is one dot between the time 10 s and 30 s, the spacing between the dots indicate a 10 s time interval. The dot between 10 s and 30 s will mark a time of 20 s. The horse is moving to the left, as time increases to the left, so the rightmost dot must be at 0 s. We will use the definition of velocity in Equation 1.2, $v = \Delta x/\Delta t$. Looking at Figure P1.12, it should be noted that you can't determine the distance information to better than 10 m and certainly not to 1 m. As a result 100 m has two significant figures (you know it is between 90 m and 110 m) and 50 m has one significant figure (you know it is between 40 m and 60 m). For this reason the answer to part (b) should have only one significant figure.
**(a)** Referring to the P1.12 in the text, $x_\text{f} = 500$ m, $x_\text{i} = 600$ m, $t_\text{f} = 10$ s, $t_\text{i} = 0$ s, so

$$v = \frac{\Delta x}{\Delta t} = \frac{500\text{ m} - 600\text{ m}}{10\text{ s} - 0\text{ s}} = \frac{-100\text{ m}}{10\text{ s}} = -10\text{ m/s}$$

**(b)** Here, $x_\text{f} = 300$ m, $x_\text{i} = 350$ m, $t_\text{f} = 40$ s, $t_\text{i} = 30$ s, so

$$v = \frac{\Delta x}{\Delta t} = \frac{300\text{ m} - 350\text{ m}}{40\text{ s} - 30\text{ s}} = \frac{-50\text{ m}}{10\text{ s}} = -5\text{ m/s}$$

**(c)** In this case, $x_\text{f} = 50$ m, $x_\text{i} = 250$ m, $t_\text{f} = 70$ s, $t_\text{i} = 50$ s, so

$$v = \frac{\Delta x}{\Delta t} = \frac{50\text{ m} - 250\text{ m}}{70\text{ s} - 50\text{ s}} = \frac{-200\text{ m}}{20\text{ s}} = -10\text{ m/s}$$

**Assess:** Displacement and velocities are signed quantities. Since the *x*-axis increases to the right and the horse is traveling to the left, we should expect all the velocities to be negative.

**P1.13. Strategize:** Average velocity is defined as the displacement $\Delta x$ divided by the time interval $\Delta t$.
**Prepare:** We are given $\Delta t = 35$ s, but we will do a preliminary calculation to find the displacement.

$$\Delta x = x_\text{f} - x_\text{i} = -47\text{ m} - (-12\text{ m}) = -35\text{ m}$$

**Solve:**

$$v = \frac{\Delta x}{\Delta t} = \frac{-35\text{ m}}{35\text{ s}} = -1.0\text{ m/s}$$

**Assess:** The answer is reasonable, and agrees with the approximate walking speed estimated in Example 1.5. The negative sign tells us that Harry is walking to the left.

**P1.14. Strategize:** Average velocity is defined as the displacement $\Delta x$ divided by the time interval $\Delta t$.
**Prepare:** We are given the initial and final positions, and the time interval, so we can use the definition of velocity, which is given in Equation 1.2.
**Solve:** $x_\text{f} = 3$ m, $x_\text{i} = -12$ m, $\Delta t = 10$ s, so

$$v = \frac{\Delta x}{\Delta t} = \frac{3\text{ m} - (-12)\text{ m}}{10\text{ s}} = \frac{15\text{ m}}{10\text{ s}} = +1.5\text{ m/s}$$

which should be reported as $+2$ m/s to one significant figure.
**Assess:** Note that it's important to keep track of signs on positions and displacements in equations.

**P1.15. Strategize:** We want to find the highest speed, meaning the highest value of: speed $= \dfrac{\Delta x}{\Delta t}$.

**Prepare:** Since we are told the times after intervals of 100 m, the $\Delta x$ is the same over each interval. Only $\Delta t$ changes. We need to find the shortest time interval, since that will correspond to the highest speed.

**Solve:** We find the duration of each of the four intervals:

$$\begin{aligned}\Delta t_1 &= 11.20 \text{ s}\\ \Delta t_2 &= (21.32 \text{ s}) - (11.20 \text{ s}) = 10.12 \text{ s}\\ \Delta t_3 &= (31.76 \text{ s}) - (21.32 \text{ s}) = 10.44 \text{ s}\\ \Delta t_4 &= (43.18 \text{ s}) - (31.76 \text{ s}) = 11.42 \text{ s}\end{aligned}$$

**(a)** Clearly the second 100 m was done in the shortest amount of time. So the second 100 m was the fastest.

**(b)** speed $= \dfrac{\Delta x}{\Delta t} = \dfrac{100 \text{ m}}{10.12 \text{ s}} = 9.88 \text{ m/s}$

**Assess:** This is about 22 mph: extremely fast for a human, but still entirely plausible.

**P1.16. Strategize:** These are all simple unit conversions. SI units refer to the base units such as meters and seconds, with no scaling prefix. For example, we want to write $1\ \mu\text{s}$ as $10^{-6}$ s. We will keep all original significant digits, since these metric conversions are exact.

**Prepare:** We first collect the necessary conversion factors: $1\ \mu\text{s} = 10^{-6}$ s; $1 \text{ km} = 10^3$ m; $1 \text{ m} = 10^2$ cm; $1 \text{ h} = 60$ min; $1 \text{ min} = 60$ s.

**Solve:**

**(a)** $9.12\ \mu\text{s} = (9.12\ \mu\text{s})\left(\dfrac{10^{-6} \text{ s}}{1\ \mu\text{s}}\right) = 9.12\times10^{-6} \text{ s}$

**(b)** $3.42 \text{ km} = (3.42 \text{ km})\left(\dfrac{10^{3} \text{ m}}{1 \text{ km}}\right) = 3.42\times10^{3} \text{ m}$

**(c)** $44 \text{ cm/ms} = 44\left(\dfrac{\text{cm}}{\text{ms}}\right)\left(\dfrac{10^{-2} \text{ m}}{1 \text{ cm}}\right)\left(\dfrac{1 \text{ ms}}{10^{-3} \text{ s}}\right) = 4.4\times10^{2} \text{ m/s}$

**(d)** $80 \text{ km/h} = 80\left(\dfrac{\text{km}}{\text{h}}\right)\left(\dfrac{10^{3} \text{ m}}{1 \text{ km}}\right)\left(\dfrac{1 \text{ h}}{3.6\times10^{2} \text{ s}}\right) = 22 \text{ m/s}$

**Assess:** The conversion factors are applied in such a manner that we obtain the desired units. Scientific notation is used and the answer has no more significant figures than the starting number.

**P1.17. Strategize:** These are all simple unit conversions. SI units refer to the base units such as meters and seconds, with no scaling prefix. In particular, we do not want to use imperial units like feet or inches.

**Prepare:** We first collect the necessary conversion factors: $1 \text{ in} = 2.54$ cm; $1 \text{ cm} = 10^{-2}$ m; 1 ft = 12 in; $39.37 \text{ in} = 1$ m; $1 \text{ mi} = 1.609$ km; $1 \text{ km} = 10^3$ m; $1 \text{ h} = 3600$ s.

**Solve:**

**(a)** $8.0 \text{ in} = 8.0 \text{ (in)}\left(\dfrac{2.54 \text{ cm}}{1 \text{ in}}\right)\left(\dfrac{10^{-2} \text{ m}}{1 \text{ cm}}\right) = 0.20 \text{ m}$

**(b)** $66 \text{ ft/s} = 66\left(\dfrac{\text{ft}}{\text{s}}\right)\left(\dfrac{12 \text{ in}}{1 \text{ ft}}\right)\left(\dfrac{1 \text{ m}}{39.37 \text{ in}}\right) = 20 \text{ m/s}$

**(c)** $60 \text{ mph} = 60\left(\dfrac{\text{mi}}{\text{h}}\right)\left(\dfrac{1.609 \text{ km}}{1 \text{ mi}}\right)\left(\dfrac{10^{3} \text{ m}}{1 \text{ km}}\right)\left(\dfrac{1 \text{ h}}{3600 \text{ s}}\right) = 27 \text{ m/s}$

**P1.18. Strategize:** The SI unit of time is seconds. So this is a simple time conversion from various units into seconds.
**Prepare:** We first need the necessary conversion factors: 1 year = 365.25 days; 1 day = 24 hours; 1 h = 3600 s.

**Solve: (a)** $1.0\text{ hour} = 1.0\text{ (h)}\left(\dfrac{3600\text{ s}}{1\text{ h}}\right) = 3600\text{ s} = 3.6\times10^3\text{ s}$

**(b)** $1.0\text{ day} = 1.0\text{ (d)}\left(\dfrac{24\text{ hours}}{1\text{ d}}\right)\left(\dfrac{3600\text{ s}}{1\text{ h}}\right) = 8.6\times10^4\text{ s}$

**(c)** $1.0\text{ year} = 1.0\text{ (year)}\left(\dfrac{365.25\text{ days}}{1\text{ year}}\right)\left(\dfrac{8.64\times10^4\text{ s}}{1\text{ d}}\right) = 3.2\times10^7\text{ s}$

**Assess:** Since the given information contains only two significant figures, all answers contain only two significant figures.

**P1.19. Strategize:** Review the rules for significant figures in Section 1.4 of the text.
**Prepare:** Pay particular attention to any zeros and whether or not they are significant. Note for example that the left-most zero in (c) is a place-holder and is not a significant digit, but the right-most zero in (c) specifies an additional digit of precision and is significant.
**Solve: (a)** The number 6.21 has three significant figures.
**(b)** The number 62.1 has three significant figures.
**(c)** The number 0.620 has three significant figures.
**(d)** The number 0.062 has two significant figures.
**Assess:** In part (c), the final zero is significant because it is expressed and in part (d), the second zero locates the decimal point but is not significant.

**P1.20. Strategize:** Review the rules for significant figures in Section 1.4 of the text.
**Prepare:** Pay particular attention to any zeros and whether or not they are significant.
**Solve: (a)** The number 0.621 has three significant figures.
**(b)** The number 0.006200 has four significant figures.
**(c)** The number 1.0621 has five significant figures.
**(d)** The number $6.21\times10^3$ has three significant figures.
**Assess:** In part (b), the initial two zeros place the decimal point. The last two zeros do not have to be there, but when they are they are significant.

**P1.21. Strategize:** Review the rules for significant figures in Section 1.4 of the text.
**Prepare:** Pay particular attention to the rules for addition (and subtraction) and multiplication (and division).
**Solve: (a)** $33.3\times25.4 = 846$
**(b)** $33.3 - 25.4 = 7.9$
**(c)** $\sqrt{33.3} = 5.77$
**(d)** $333.3 \div 25.4 = 13.1$
**Assess:** In part (a) the two numbers multiplied each have three significant figures and the answer has three significant figures. In part (b), even though each number has three significant figures, no information is significant past the tenths column. As a result, the answer is expressed only to the tenths column. In part (c), the number and the answer both have three significant figures. In part (d) the answer is expressed to three significant figures since this is the least number of significant figures in either of the two numbers in the problem.

**P1.22. Strategize:** The number of significant digits should reflect the certainty of the measurement. A digit that is not certain should not be specified.
**Prepare:** The uncertainty is nearly a half an inch in either direction; this is about one centimeter in either direction, so we'll express the answer to the nearest centimeter.
**Solve:** Convert the man's height to inches: 6 ft 1 in = 73 in.

$$73\text{ in}\left(\frac{2.54\text{ cm}}{1\text{ in}}\right)\left(\frac{1\text{ m}}{100\text{ cm}}\right) = 1.85\text{ m}$$

**Assess:** To round this to two significant figures, 1.9 m, would give the wrong impression of the man's height.

**P1.23. Strategize:** This is a simple unit conversion.
**Prepare:** To convert, we will use the fact that each foot contains exactly 12 inches, and each inch is 2.54 cm, or 0.0254 m.
**Solve:** We have: $29{,}029\ \text{ft}\left(\dfrac{12\ \text{in}}{1\ \text{ft}}\right)\left(\dfrac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right) = 8.8480\times10^3\ \text{m}.$
**Assess:** Note that we have used exact conversions, such that there was no loss of significant digits in the conversion. The information was given to five significant digits, and we still have five significant digits.

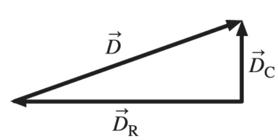
**P1.24. Strategize:** This is an estimation problem. We will need to assemble estimates from life experience, and many answers are possible.
**Prepare:** First make an estimate of how much you cut and how often you mow. Let's say you cut an inch per week. Then it's just a matter of unit conversion to get it into m/s.
**Solve:** $v = \left(\dfrac{1\ \text{in}}{1\ \text{week}}\right)\left(\dfrac{1\ \text{week}}{7\ \text{day}}\right)\left(\dfrac{1\ \text{day}}{24\ \text{hr}}\right)\left(\dfrac{1\ \text{hr}}{3.3\times10^3\ \text{s}}\right)\left(\dfrac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right) = 4\times10^{-8}\ \text{m/s}$
**Assess:** Since a week is very large compared to a second and a m is about 40 times the size of an inch, we are expecting a very small number. Even professional grass growing watchers don't expect to see much activity in one second.

**P1.25. Strategize:** This is an estimation problem. We will need to assemble estimates from life experience, and many answers are possible.
**Prepare:** My barber trims about an inch of hair when I visit him every month for a haircut. The rate of hair growth thus is one inch per month. We also need the conversions $1\ \text{in} = 2.54\ \text{cm}$, $1\ \text{day} = 24\ \text{h}$, $1\ \text{month} = 30\ \text{days}$, $1\ \text{h} = 3600\ \text{s}$, $1\ \text{cm} = 10^{-2}\ \text{m}$.
**Solve:** The rate of hair growth is

$$\left(\frac{1\ \text{in}}{\text{month}}\right)\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\frac{10^{-2}\ \text{m}}{1\ \text{cm}}\right)\left(\frac{1\ \text{month}}{30\ \text{d}}\right)\left(\frac{1\ \text{d}}{24\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 9.8\times10^{-9}\ \text{m/s} \approx 35\ \mu\text{m/h}$$

**Assess:** Since we expect an extremely small number for the rate at which our hair grows per second, this figure is not unreasonable.

**P1.26. Strategize:** We are asked for the straight-line distance between two places. This is the same as the magnitude of the displacement between two locations, so we can view this as a displacement problem.
**Prepare:** To find the total distance between the workplaces, we can calculate the displacement from Robin's workplace to Carol's workplace.
**Solve:** The displacement from the house to Robin's workplace is 7.5 km west. The displacement from the house to Carol's workplace is 2.0 km north. Refer to the diagram below.

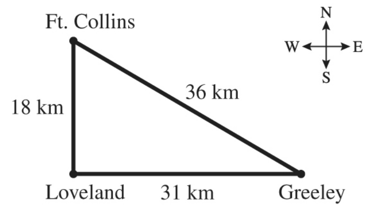



The total displacement between Robin's workplace and Carol's workplace is the length of the hypotenuse of the triangle in the figure. This is

$$D = \sqrt{(D_R)^2 + (D_C)^2} = \sqrt{(7.5\ \text{km})^2 + (2.0\ \text{km})^2} = 7.8\ \text{km}$$

**Assess:** Since the displacements are in different directions, we must treat them as vectors.

**P1.27. Strategize:** We are asked for the straight-line distance between two places. This is the same as the magnitude of the displacement between two locations, so this could be viewed as a displacement problem.
**Prepare:** In this problem we need to find the distance between Fort Collins and Greeley. We'll use the Pythagorean theorem.
**Solve:**

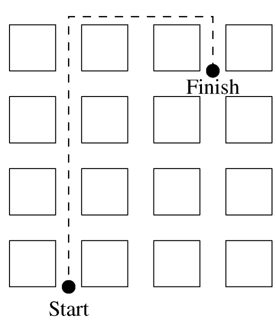



$$\sqrt{(18\text{ km})^2+(31\text{ km})^2}=36\text{ km}$$

**Assess:** This is a reasonable distance between cities.

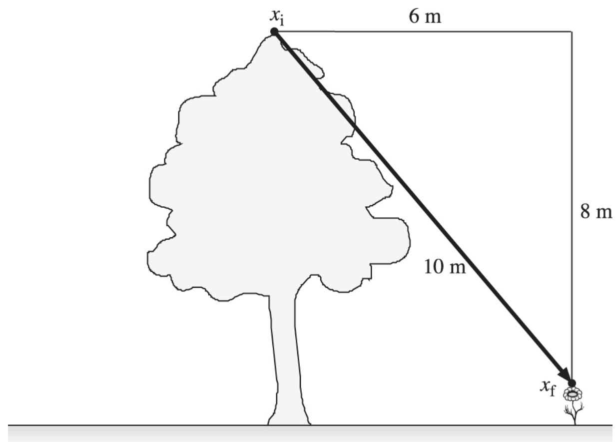
**P1.28. Strategize:** We are asked for the straight-line distance between two places. This is the same as the magnitude of the displacement between two locations, so this could be viewed as a displacement problem.
**Prepare:** Joe and Max went at right angles to each other, so we can use the Pythagorean theorem to compute the distance between them.
**Solve:** $d=\sqrt{(3.25\text{ km})^2+(0.55\text{ km})^2}=3.3\text{ km}$
**Assess:** It is right that the difference between the two is greater than the distance either of them went; the answer seems about right for a skinny triangle.

**P1.29. Strategize:** This problem is asking for the straight-line distance between initial and final points, given a number of smaller legs of the journey. A picture may be beneficial.
**Prepare:** We begin by sketching a drawing of the setup.




Clearly Veronica travels four blocks north, but then comes back one block south, such that she is finally three blocks north of her starting point. She also moves two blocks east. We can use the Pythagorean Theorem to combine these displacements in the east and north directions into one straight line distance.
**Solve:** The component of displacement eastward is $\Delta x=2(400\text{ ft})=800\text{ ft}$, and the displacement northward is $\Delta y=3(280\text{ ft})=840\text{ ft}$. Then the total displacement is $d=\sqrt{\Delta x^2+\Delta y^2}=\sqrt{(800\text{ ft})^2+(840\text{ ft})^2}=1.16\times10^3\text{ ft}$.
**Assess:** This is a reasonable distance. One way of checking this would be to compare it to the distance required to walk two blocks east and then three blocks north, which is 1,640 ft. The straight-line distance is shorter, as it should be.

**P1.30. Strategize:** This is a displacement problem. Displacement is the difference between initial and final positions.
**Prepare:** The displacement is the hypotenuse of a right triangle whose legs are 6 m (half the width of the garden) and 8 m, directed from $x_\text{i}$ at the top of the tree to $x_\text{f}$ at the top of the flower.



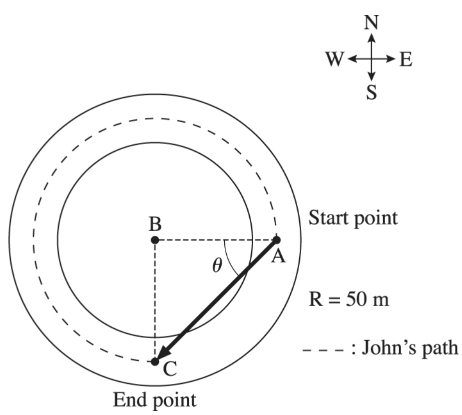

**Solve:** The length of the hypotenuse is $\sqrt{(6\text{ m})^2 + (8\text{ m})^2} = 10\text{ m}$.

**Assess:** Displacement is a vector and does have direction (as mentioned in the Prepare step), but we were only asked for the magnitude of the displacement.

**P1.31. Strategize:** This is a displacement problem. The displacement is the difference between initial and final locations: $\Delta\vec{x} = \vec{x}_f - \vec{x}_i$. Because this is two-dimensional motion, the vector nature of the displacement is important; we must provide a magnitude and a direction.

**Prepare:** John's displacement is the vector from his starting point to his ending point.

**Solve:** Refer to the diagram below.




John stops at the southernmost end of the circle. His final position is 50 m west and 50 m south of his starting position since the radius of the circle is 50 m. We must find the displacement vector from the initial point to the final point.
Point $B$ is at the center of the circle.
The displacement vector has a length of

$$\overline{AC} = \sqrt{\overline{AB}^2 + \overline{BC}^2} = \sqrt{(50\text{ m})^2 + (50\text{ m})^2} = 71\text{ m}$$

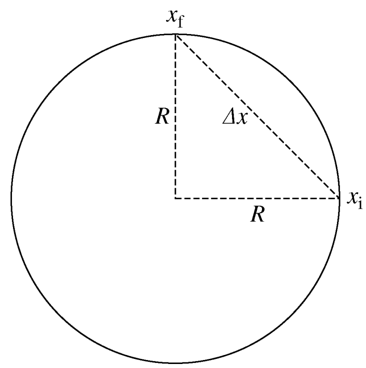
The angle in the diagram is

$$\theta = \arctan\left(\frac{1.0\text{ m}}{1.0\text{ m}}\right) = 45°$$

So the answer in (magnitude, direction) notation would be (71 m, 45° south of west).

**Assess:** Compare the solution to the solution for Problem 1.27. Here it would be difficult to sum his displacement vectors along the circle, but this is not necessary since the displacement vector is always the vector from the initial position to the final position.

**P1.32. Strategize:** This problem requires us to use the concept of displacement (the difference between two positions) and relate it to the geometry of a lake.
**Prepare:** If we look at the figure below, it is clear that the straight-line displacement is related to the radius of the circle in a simple way: $(\Delta x)^2 = R^2 + R^2 = 2R^2$.




**Solve:** Using the geometric information from the figure above, we have $\Delta x = \sqrt{2}R,$ and we also know that $\Delta x = x_f - x_i = 180$ m. Combining these two, we have $R = (180\text{ m})/\sqrt{2} \Rightarrow D = 2R = \sqrt{2}(180\text{ m}) = 255$ m.
**Assess:** Clearly this diameter is the right order of magnitude. We also expect that the straight line distance must be shorter than $2R$ (as seen from the figure), and it is.

**P1.33. Strategize:** We must consider two separate displacements and use them to find a total displacement.
**Prepare:** Knowing that the total trip consists of two displacements, we can add the two displacements to determine the total displacement and hence the distance of the goose from its original position. A quick sketch will help you visualize the two displacements and the total displacement.
**Solve:** The distance of the goose from its original position is the magnitude of the total displacement vector. This is determined as follows:

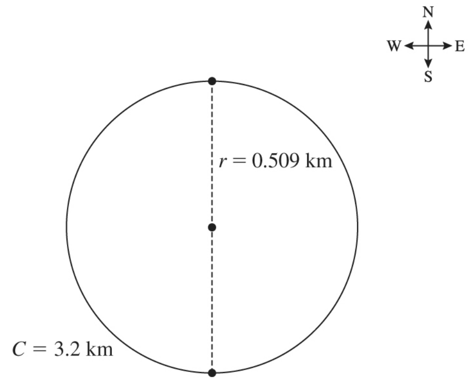
$$\text{d} = \sqrt{(32\text{ km})^2 + (20\text{ km})^2} = 38\text{ km}$$

**Assess:** A quick look at your sketch shows that the total distance should be larger than the largest leg of the trip and this is the case.

**P1.34. Strategize:** This problem contrasts the concepts of distance and displacement. Distance is what is measured by the odometer of a car, and depends on the path taken between two points. Displacement is the difference between two positions, and only depends on the two endpoints. Displacement does not depend on the path taken between the two endpoints.

**Prepare:** We can solve for the radius of the track from $C = 2\pi r \Rightarrow r = \dfrac{C}{2\pi} = \dfrac{3.2\text{ km}}{2\pi} = 0.509\text{ km}$

**Solve:**

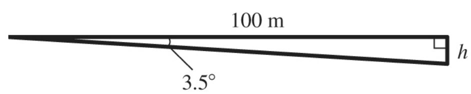



**a.** The car has traveled half of the circumference, or $3.2\text{ km}/2 = 1.6\text{ km}$
**b.** The displacement of the car is the diameter (twice the radius) of the track north of its starting point.

$$D = 2(0.509\text{ km}) = 1.0\text{ km}$$

**Assess:** The distance traveled is longer than the displacement, as we would expect.

**P1.35. Strategize:** This problem involves motion in two orthogonal directions: vertical and horizontal. We can use trigonometry to relate the distances and the given angle.
**Prepare:** It is helpful to draw a diagram.




**Solve:** Use knowledge about right triangles from trigonometry.

$$\tan 3.5° = \frac{h}{100\text{ m}} \Rightarrow h = (100\text{ m})(\tan 3.5°) = 6.1\text{ m}$$

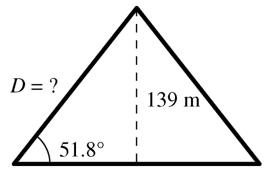
The vulture loses 6.1 m of height as it flies 100 m horizontally.
**Assess:** This small loss of height would indeed allow a vulture to glide long distances.

**P1.36. Strategize:** This problem involves a displacement in both the horizontal and vertical directions ($x$ and $y$). Displacement is the difference between the final and initial locations, and does not depend on the twists and turns in between.
**Prepare:** We calculate the $x$ and $y$ components separately and combine them using the Pythagorean Theorem. We associate the positive $x$ direction with motion horizontally to the right in the map, and $y$ will be the direction vertically upward on the map. We can determine the direction of the displacement using trigonometry. For example, we can determine the angle away from the positive $x$ axis by using $\tan(\theta) = \Delta y / \Delta x$.
**Solve:** The horizontal displacement is given by $\Delta x = (0.80\text{ mi}) + (1.20\text{ mi})\cos(30°) = 1.84\text{ mi}$. The vertical displacement is given by $\Delta y = (-0.80\text{ mi}) + (1.20\text{ mi})\sin(30°) = -0.20\text{ mi}$. We combine these using the Pythagorean Theorem: $d = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(1.84\text{ mi})^2 + (-0.20\text{ mi})^2} = 1.9\text{ mi}$.

Then $\tan(\theta) = \dfrac{\Delta y}{\Delta x} = \dfrac{-0.20\text{ mi}}{1.84\text{ mi}} = -6.2°$, meaning the displacement is 1.9 miles at an angle of 6.2° below the positive $x$ axis.

**Assess:** This is a reasonable displacement, given that the sum of the legs of the trip is 2.8 miles. We expect the straight-line distance between initial and final points to be less than the sum of distances (with twists and turns) that Olivia took. And we see this is the case.

**P1.37. Strategize:** We must use simple trigonometry to relate the height and distance along the slope of the Great Pyramid.
**Prepare:** We begin by making a sketch of the geometry described:

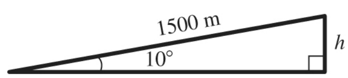



Clearly, we can relate the distance along the sloped side to the height by using the sine trigonometric function.

**Solve:** We know $\sin(\theta) = \frac{\text{opposite}}{\text{adjacent}} = \frac{h}{D}$, so $D = \frac{h}{\sin(\theta)} = \frac{139\text{ m}}{\sin(51.8°)} = 177$ m.

**Assess:** We know that the distance along the slope should be greater than the height, and we know from the given angle that it should not very much greater. Our answer of 177 m makes sense.

**P1.38. Strategize:** This problem involves displacement vertically and horizontally. The distances along different directions can be related to the given angle using trigonometry.
**Prepare:** It is helpful to draw a diagram.

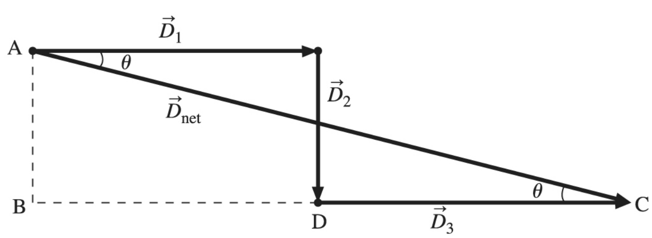



**Solve:** Use knowledge about right triangles from trigonometry.

$$h = (1500\text{ m})(\sin 10°) = 260\text{ m}$$

The hiker gains 260 m of elevation.
**Assess:** 260 m is quite a bit less than 1500 m, but this is expected.

**P1.39. Strategize:** In this problem we have three displacements to add using the laws of vector addition.
**Prepare:** We will use the diagram below.




$\overline{AB} = 40$ cm
$\overline{BD} = 60$ cm
$\overline{DC} = 80$ cm
$\overline{BC} = 60\text{ cm} + 80\text{ cm} = 140$ cm

**Solve:** A convenient place to place the origin is the origin of the motion. We could add the first two vectors and then add the third vector on to that result. However, by looking at the diagram, the total displacement in the *x* direction is $60\text{ cm} + 80\text{ cm} = 140\text{ cm}$ to the right. The total displacement in the *y* direction is 40 cm downward. The net displacement will reflect these two displacements, so the result of the vector addition will be a vector pointing 140 cm to the right and 40 cm downward. Considering the right triangle *ABC* in the diagram, the magnitude of the displacement vector is then

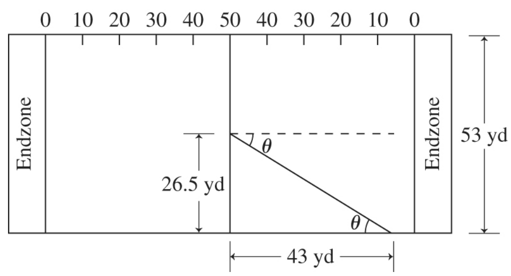
$$\overline{AC} = \sqrt{\overline{AB}^2 + \overline{BC}^2} = \sqrt{(140\text{ cm})^2 + (40\text{ cm})^2} = 150\text{ cm}$$

Where we have assumed that the measurements in the problem have been given to two significant figures.

The angle that the vector makes is $\theta = \arctan\left(\frac{40 \text{ cm}}{140 \text{ cm}}\right) = 16°$ below the positive $x$-axis.

**Assess:** When adding any number of displacements, the net displacement is always the vector between the initial and final point of the motion.

**P1.40.** **Strategize:** We must determine the displacement of the ball using the information given about the motion down the field and toward the sidelines (orthogonal directions).
**Prepare:** We know the initial position of the ball (the middle of the field). We know the ball travels 43 yards down field (the first displacement) and 26.5 yards to the side of the field (the second displacement). We can add these two displacements to obtain the net displacement (magnitude and direction). A quick sketch will help you visualize the two displacements and the net displacement.




**Solve:** The magnitude of the net displacement may be obtained by

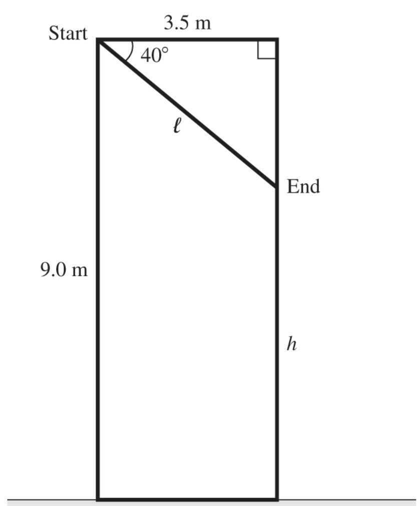
$$d = \sqrt{(43 \text{ yd})^2 + (26.5 \text{ yd})^2} = 50 \text{ yd}$$

The direction of the net displacement may be obtained by

$$\theta = \tan^{-1}\left(\frac{26.5 \text{ yd}}{43 \text{ yd}}\right) = 32°$$

The net displacement is 50 yd in a direction 32 degrees from straight down the middle of the field.
**Assess:** Knowing the two displacements, we can add them to determine the net displacement (magnitude and direction). Looking at your sketch, you should expect the magnitude of the net displacement to be larger than either of the two displacements which contribute to the net displacement, and this is the case. Looking at your sketch, you should also expect the angle of the net displacement to be less than 45°, and this is the case.

**P1.41.** **Strategize:** Because this problem involves motion in two orthogonal directions, it will involve a right triangle. We can use trigonometry to relate given distances and angles.
**Prepare:** Draw a diagram of the situation. Note the right triangle.



**Solve:** Use knowledge about right triangles from trigonometry.
**(a)** The length of the path is

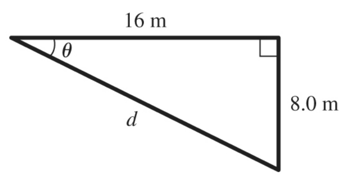
$$\ell = \frac{3.5 \text{ m}}{\cos 40°} = 4.6 \text{ m}$$

**(b)** The height $h$ above the ground is the vertical side of the triangle subtracted from 9.0 m.

$$h = 9.0 \text{ m } - (3.5 \text{ m})(\tan 40°) = 6.1 \text{ m}$$

**Assess:** Because of the angle we expect the squirrel to lose less height than the horizontal distance traveled.

**P1.42. Strategize:** Because this problem involves motion in two orthogonal directions, it will involve a right triangle. We can relate the given distances to the required angle using trigonometry.
**Prepare:** Draw a diagram of the situation. Note the right triangle.




**Solve:** Use knowledge about right triangles from trigonometry.
**(a)** The angle of the path below the horizontal is

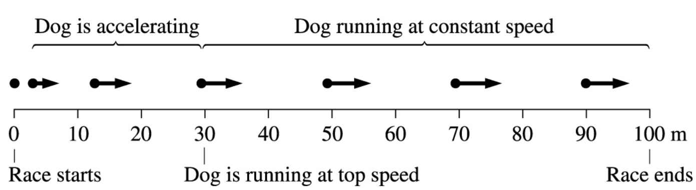
$$\theta = \arctan\left(\frac{8 \text{ m}}{16 \text{ m}}\right) = 27°$$

**(b)** The distance $d$ covered is

$$d = \sqrt{(16 \text{ m})^2 + (8.0 \text{ m})^2} = 18 \text{ m}$$

**Assess:** Because the squirrel descended less than the horizontal distance we expect the angle to be less than 45 degrees.

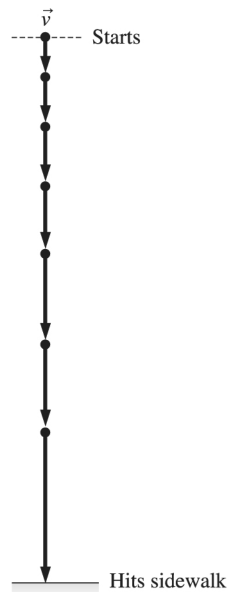
**P1.43.** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the dog's speed.
**Prepare:** Since the dog accelerates for 30 m, the position dots will be successively farther apart and the velocity vectors will increase for this part of the race. After the dog reaches its top speed (at 30 m), the position dots are uniformly spaced and the velocity vectors are all the same length.
**Solve:**




**Assess:** While the dog is accelerating, the dot spacing and the velocity vector must increase, and they do. While the dog is traveling at a constant speed the dot spacing and the velocity vector must remain the same, and they do.

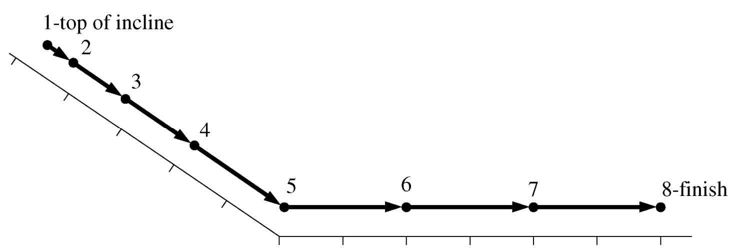
**P1.44. Strategize:** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the watermelon's speed.
**Prepare:** The watermelon, represented as a particle, falls freely and speeds up during its downward motion along the $y$-direction. The velocity vectors are thus of increasing length.

**Solve:**




**Assess:** As a result of the acceleration due to gravity, as the watermelon falls, its velocity and the distance between the position dots increases. This is the case in the figure shown.

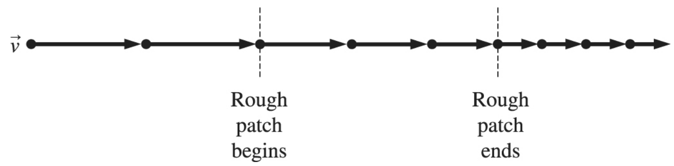
**P1.45.** **Strategize:** We will draw the motion diagram with velocity vectors initially pointing down an incline and then leveling off to travel over flat ground.
**Prepare:** The length of velocity arrows and spacing between dots will increase as the skater rolls down the incline. Once the skater reaches the end of the incline, the skater will move at a constant speed. So on level ground the arrows should be a constant length and the dots should be equally-spaced.
**Solve:**




**Assess:** We expect the speed to increase as the skater moves down the incline, and then remain steady. This is reflected in the diagram above.

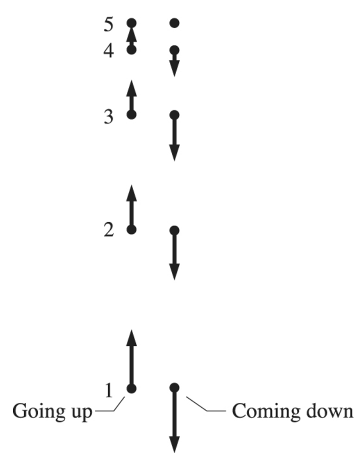
**P1.46.** **Strategize:** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the skater's speed.
**Prepare:** The skater moves along the $x$-axis. She slows down or has decreasing velocity vectors during a patch of rough ice. She has constant velocity vectors before the rough patch begins and after the rough patch ends, that is, velocity vectors are of the same length.

**Solve:**



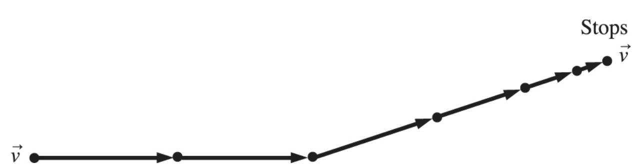

**Assess:** Before and after the rough ice, the velocity vector is constant in length and the position dots are uniformly spaced. Since the skater is traveling slower after the rough ice than before, the velocity vectors after the rough ice are shorter than they are before the rough ice and the position dots are closer together after the rough ice than they are before the rough ice. During the rough ice section, the velocity vector decreases in length and the dot position gets closer together.

**P1.47. Strategize:** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the eland's speed.
**Prepare:** Since the eland has a positive velocity but is slowing down, the velocity will decrease to zero and the spacing between the position dots will decrease. The velocity vector at each position on the way up has the same magnitude but opposite direction as the velocity at each position on the way down.
**Solve:**



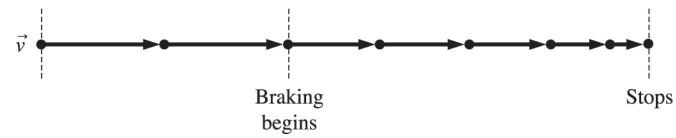

**Assess:** On the way up, the velocity vector decreases to zero as it should and the spacing between the position dots decreases as it should. The magnitude of the velocity vector at any position is the same on the way up as it is on the way down. This allows us to conclude that the figure is correct.

**P1.48. Strategize:** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the ball's speed.
**Prepare:** Represent the ball as a particle which is moving along the ramp defined as the $x$-axis. As the ball rolls up the ramp, it slows down. The velocity vector along the ramp is smaller than the vector along the floor.
**Solve:**




**Assess:** While the ball is traveling across the horizontal section, the velocity vector and the spacing of the position dots is constant. As the ball makes the transition from the horizontal section to the ramp, there is a change in velocity. As the ball travels up the ramp the velocity vectors decrease in length and the position dots to get closer together.

**P1.49. Strategize:** We interpret the described motion in a motion diagram. We assume equal time intervals between dots, and we draw velocity vectors with their length proportional to the car's speed.
**Prepare:** The motorist, represented as a particle, is moving along the $x$-axis. He slows down during braking. During his reaction time his velocity doesn't change.
**Solve:**




**Assess:** During the reaction time the velocity vector is constant in length and the position dots are uniformly spaced. During the braking process, the velocity vector decreases in length and the position dots get closer together.

**P1.50. Strategize:** Note any changes in velocity vectors, and make a physically plausible explanation for the changes.
**Prepare:** Keep in mind that the dots represent the position of an object at equal time intervals and the vectors represent the velocity of the object at these times.
**Solve:** Rahul was coasting on interstate highway I-44 from Tulsa to Springfield at 70 mph. Seeing an accident at a distance of 200 feet in front of him, he began to brake. What steady deceleration will bring him to a stop at the accident site?
**Assess:** Since the position dots are initially equally spaced and the first few velocity vectors have the same length, this is consistent with Rahul initially traveling at a constant velocity. The fact that the dots get closer together and the velocity vectors get shorter is consistent with Rahul's braking. The fact that there is no velocity vector associated with the last dot is consistent with the fact that he braked to a stop.

**P1.51. Strategize:** Note any changes in velocity vectors, and make a physically plausible explanation for the changes.
**Prepare:** Keep in mind that the dots represent the position of an object at equal time intervals and the vectors represent the velocity of the object at these times.
**Solve:** Reema passes 3rd Street doing 40 mph, slows steadily to the stop sign at 4th Street, stops for 1 s, then speeds up and reaches her original speed as she passes 5th Street. If the blocks are 50 m long, how long does it take Reema to drive from 3rd Street to 5th Street?
**Assess:** The statement that Reema slows to a stop in one block and regains her initial velocity in one block is consistent with the symmetry of the position dots and the velocity vectors about the stop position.

**P1.52. Strategize:** Note any changes in velocity vectors, and make a physically plausible explanation for the changes.
**Prepare:** Keep in mind that the dots represent the position of an object at equal time intervals and the vectors represent the velocity of the object at these times.
**Solve:** A race car slows down from an initial speed of 100 mph to 50 mph in order to negotiate a tight turn. After making the 90° turn the car accelerates back up to 100 mph in the same time it took to slow down.
**Assess:** The statement that the car slows down and speeds up in the same time is consistent with the symmetry of the spacing of the position dots and the length of the velocity vectors of the car going into and coming out of the curve. The statement that the car takes the curve at a constant speed is consistent with the fact that all the velocity vectors have the same length as the car negotiates the curve.

**P1.53. Strategize:** Note any changes in velocity vectors, and make a physically plausible explanation for the changes.
**Prepare:** Keep in mind that the dots represent the position of an object at equal time intervals and the vectors represent the velocity of the object at these times. We can construct a situation to match the motion diagram.
**Solve:** A bowling ball is at rest at the top of an incline. You nudge the ball giving it an initial velocity and causing it to roll down an incline. At the bottom of the incline it bounces off a sponge and travels back up the incline until it stops.

**Assess:** The statement that you give the ball an initial velocity is consistent with the fact that the start position dot has a velocity vector. The statement that the ball rolls down the incline is consistent with the fact that the dots are getting farther apart and the velocity vectors are increasing in length. The statement that the ball bounces off a sponge is consistent with the fact that ball does not bounce back to its original position.

**P1.54. Strategize:** Note any changes in velocity vectors, and make a physically plausible explanation for the changes.
**Prepare:** Keep in mind that the dots represent the position of an object at equal time intervals and the vectors represent the velocity of the object at these times. We can construct a situation to match the motion diagram.
**Solve:** Phil is standing on a third floor balcony, 10 m above the ground. He throws a ball with a speed of 20 m/s at an upward-angle of 30°. Where does the ball hit the ground?
**Assess:** The statement that the ball is kicked from the third floor and lands on the ground is consistent with the difference in heights of the start and end positions. Knowing that the ball slows down on the way up and speeds up on the way down is consistent with the fact that the position dots get closer together and the velocity vectors get shorter on the way up and the position dots get farther apart and the velocity vectors longer on the way down.

**P1.55. Strategize:** This is an estimation problem, so many different answers are possible.
**Prepare:** We must first estimate a human lifespan, and then do a series of unit conversions. A human lifespan depends heavily on where that human lives and on risk factors. For humans with ready access to medicines and without serious risk factors, at lifespan of 80 years is reasonable. We use this as our estimate.
**Solve:** Converting 80 years into units of seconds, we find

$$80\text{ yr}\left(\frac{365\text{ days}}{1\text{ yr}}\right)\left(\frac{24\text{ hrs}}{1\text{ day}}\right)\left(\frac{3600\text{ s}}{1\text{ hr}}\right)=2.5\times10^{9}\text{ s}$$

**Assess:** We expect an extremely large number, since there are already thousands of seconds in just a single hour. This answer is reasonable.

**P1.56. Strategize:** We are asked for the average speed, which is given by $\text{speed}=\dfrac{\text{distance}}{\text{time}}$. It is very important to realize that $v_{\text{av}}\neq\frac{1}{2}(v_1+v_2)$, because there is no reason to think that the two speeds will be equally important.
**Prepare:** We can determine the amount of time required for each leg of the journey, and then combine our information to determine the total distance and total time.
**Solve:** For the first leg of the journey: $v_1=d_1/\Delta t_1\Rightarrow\Delta t_1=d_1/v_1=(25\text{ mi})/(55\text{ mi/hr})=0.455\text{ hr}$, and for the second leg of the journey, we have $v_2=d_2/\Delta t_2\Rightarrow\Delta t_2=d_2/v_2=(15\text{ mi})/(70\text{ mi/hr})=0.214\text{ hr}$

Now the average speed for the entire trip is $v_{\text{av}}=d_{\text{total}}/\Delta t_{\text{total}}=\dfrac{(25\text{ mi})+(15\text{ mi})}{(0.455\text{ hr})+(0.214\text{ hr})}=60\text{ mi/hr}$.

**Assess:** We do expect the average speed to be somewhere between the two speeds at which Joseph traveled. It makes sense that this is the case.

**P1.57. Strategize:** We will use the relationship $v_{\text{av}}=\dfrac{d}{\Delta t}$ to determine the new speed required.
**Prepare:** We know that the distance between Evan and his grandmother's house does not change. But his speed and the duration of the trip will both be different today than on a normal day. Thus we will write out $v_{\text{av,norm}}=\dfrac{d}{\Delta t_{\text{norm}}}$ and $v_{\text{av,today}}=\dfrac{d}{\Delta t_{\text{today}}}$ separately and then relate the two.
**Solve:** From the information about ordinary days, we know

$$d=v_{\text{av,norm}}\Delta t_{\text{norm}}=(55\text{ mi/hr})(25\text{ min})\left(\frac{1\text{ hr}}{60\text{ min}}\right)=22.9\text{ mi}$$

Now we can use this distance, and the fact that Evan must make the trip in 5 minutes less than usual to write

$$v_{\text{av,today}} = \frac{d}{\Delta t_{\text{today}}} = \frac{(22.9 \text{ mi})}{(20 \text{ min})}\left(\frac{60 \text{ min}}{1 \text{ hr}}\right) = 69 \text{ mph.}$$

**Assess:** Since Evan has to make the trip in 25% less time than usual, it makes perfect sense that his average speed must be 25% greater than usual.

**P1.58. Strategize:** We want to determine one average speed that Gretchen can run the entire time that is equivalent to $v_{\text{av}} = \dfrac{d_{\text{total}}}{\Delta t_{\text{total}}}$.

**Prepare:** We can consider the two segments of the race during which Gretchen ran at a constant speed, separately. That way, we can write $v_{\text{av},1} = \dfrac{d_1}{\Delta t_1}$ and $v_{\text{av},2} = \dfrac{d_2}{\Delta t_2}$, and then combine information to determine $v_{\text{av,total}} = \dfrac{d_{\text{total}}}{\Delta t_{\text{total}}} = \dfrac{d_1 + d_2}{\Delta t_1 + \Delta t_2}$.

**Solve:** We write the expression for the average speed for the whole trip and then write the two relevant times in terms of the given speeds and distances.

$$v_{\text{av,total}} = \frac{d_{\text{total}}}{\Delta t_{\text{total}}} = \frac{d_1 + d_2}{\Delta t_1 + \Delta t_2} = \frac{d_1 + d_2}{(d_1 / v_{\text{av},1}) + (d_2 / v_{\text{av},2})}$$

$$v_{\text{av,total}} = \frac{(4.0\times10^3 \text{ m}) + (1.0\times10^3 \text{ m})}{\left((4.0\times10^3 \text{ m})/(5.0 \text{ m/s})\right) + \left((1.0\times10^3 \text{ m})/(4.0 \text{ m/s})\right)} = 4.8 \text{ m/s}$$

**Assess:** It makes sense that the average speed for the entire trip would be between the two speeds Gretchen ran during the race.

**P1.59. Strategize:** We will use the expression for average speed $v_{\text{av}} = \dfrac{d}{\Delta t}$ and apply it to each leg of the swim (against the current, and with the current).

**Prepare:** In order to calculate anything about the time, we must consider how the required time will be affected when we swim with the current: $\Delta t_{\text{with}} = \dfrac{d}{v + v_{\text{w}}}$, and against the current: $\Delta t_{\text{against}} = \dfrac{d}{v - v_{\text{w}}}$. The distance is the same either way. But we also know that we want to compare the total time we get from this to the time required in still water: $\Delta t_{\text{still}} = \dfrac{2d}{v}$. Here the factor of two came from the fact that we don't need to consider two separate legs of the swim in this case. We can just write down the total two-way time.

**Solve:** We want to compare $\Delta t_{\text{with}} + \Delta t_{\text{against}}$ to $\Delta t_{\text{still}}$, so let us calculate the ratio

$$\frac{\Delta t_{\text{with}} + \Delta t_{\text{against}}}{\Delta t_{\text{still}}} = \frac{\dfrac{d}{v + v_{\text{w}}} + \dfrac{d}{v - v_{\text{w}}}}{2d / v} = \frac{1}{2}\left(\frac{1}{1 + v_{\text{w}} / v} + \frac{1}{1 - v_{\text{w}} / v}\right)$$

$$= \frac{1}{2}\left(\frac{1}{1 + (0.52 \text{ m/s})/(1.78 \text{ m/s})} + \frac{1}{1 - (0.52 \text{ m/s})/(1.78 \text{ m/s})}\right) = 1.093$$

This means the trip takes 9.3% longer taking the current into account, than it would in still water.

**Assess:** This is a reasonable fractional difference, given that the speed of the water is significantly smaller than the swimming speed in still water.

**P1.60. Strategize:** This is a simple unit conversion.
**Prepare:** The speed of the glacier has been given in feet per year. It is just a matter of unit conversion to get it into m/s.
**Solve:** The speed of the glacier in m/s is determined as follows:

$$v = \left(\frac{105\text{ ft}}{\text{yr}}\right)\left(\frac{12\text{ in}}{\text{ft}}\right)\left(\frac{2.54\text{ cm}}{1\text{ in}}\right)\left(\frac{1\text{ m}}{100\text{ cm}}\right)\left(\frac{1\text{ yr}}{3.16\times10^{7}\text{ s}}\right) = 1.0\times10^{-6}\text{ m/s}$$

**Assess:** All of the unit conversions are correct, after units are canceled we obtain the desired units (m/s) and we are expecting a very small number.

**P1.61. Strategize:**
**Prepare:** Knowing that speed is distance divided by time, the distance is the circumference of a circle of radius 93,000,000 miles and the time is one year, we can determine the speed of the earth orbiting the sun. In order to get an answer in m/s, some unit conversion will be required.
**Solve:** The speed of the earth in its orbit about the sun may be determined by

$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{t} = \frac{2\pi(9.3\times10^{7}\text{ mi})}{1\text{ yr}}\left(\frac{1\text{ yr}}{3.16\times10^{7}\text{ s}}\right)\left(\frac{1.61\times10^{3}\text{ m}}{1\text{ mi}}\right) = 3.0\times10^{4}\text{ m/s}$$

**Assess:** All of the unit conversions are correct, after units are canceled we obtain the desired units (m/s) and we are expecting a large number.

**P1.62. Strategize:** This problem is mostly a unit conversion. We will also make use of the given growth rate of the shark.
**Prepare:** The length of the shark can be converted to centimeters, and then the length can be related to an age using the given growth rate. The increase in length during the shark's lifetime can be 14 ft.
**Solve:** Starting with the increase in length, we have

$$(14\text{ ft})\left(\frac{12\text{ in}}{1\text{ ft}}\right)\left(\frac{2.54\text{ cm}}{1\text{ in}}\right)\left(\frac{1\text{ yr}}{1\text{ cm}}\right) = 430\text{ yrs.}$$

**Assess:** Although this is an incredible age, it is consistent with the statement that the Greenland shark is thought to be the longest-living vertebrate on Earth.

**P1.63. Strategize:** We will use the equation $v_{\text{av}} = \dfrac{d}{\Delta t}$ over any period when the average speed is given.
**Prepare:** We can apply the above expression to the uphill segment, the downhill segment.

$$v_{\text{av,uphill}} = \frac{d_{\text{uphill}}}{\Delta t_{\text{uphill}}}, \qquad v_{\text{av,downhill}} = \frac{d_{\text{downhill}}}{\Delta t_{\text{downhill}}},\ \text{and we also note } \Delta t_{\text{total}} = \Delta t_{\text{downhill}} + \Delta t_{\text{uphill}}$$

We know both distances, the total time and the average speed for the uphill leg. We can relate the speeds, distances and times for each segment and solve for the unknown average speed on the downhill leg.

**Solve:** Starting with $\Delta t_{\text{total}} = \Delta t_{\text{downhill}} + \Delta t_{\text{uphill}}$, and inserting $\Delta t_{\text{uphill}} = \dfrac{d_{\text{uphill}}}{v_{\text{av,uphill}}}$ we can obtain

$$\Delta t_{\text{downhill}} = \Delta t_{\text{total}} - \frac{d_{\text{uphill}}}{v_{\text{av,uphill}}} = (2{,}845\text{ s}) - \frac{(4.6\text{ mi})}{(8.75\text{ mi/hr})}\left(\frac{3600\text{ s}}{1\text{ hr}}\right) = 952\text{ s}$$

Now that we know the time, we simply use

$$v_{\text{av,downhill}} = \frac{d_{\text{downhill}}}{\Delta t_{\text{downhill}}} = \frac{6.9\text{ mi}}{952\text{ s}}\left(\frac{3600\text{ s}}{1\text{ hr}}\right) = 26\text{ mph}$$

**Assess:** This is much faster than the uphill leg of the trip, which is to be expected.

**P1.64. Strategize:** We simply calculate the speed using Equation 1.1, and compare it to the purported value.
**Prepare:** According to her speedometer, Shannon is traveling 70 mph. Knowing that mile markers are 1 mi apart and knowing that she travels the distance between two markers in 54 s, we can determine her speed and compare it to the value from the speedometer to see if her speedometer is accurate.
**Solve:** Her actual speed in mph may be determined by

$$v = \frac{\text{distance}}{\text{time}} = \left(\frac{1\text{ mi}}{54\text{ s}}\right)\left(\frac{3.6\times10^2\text{ s}}{\text{hr}}\right) = 67\text{ mph}$$

Since Shannon's speedometer reads 70 mph and her actual speed is 67 mph, we conclude that her speedometer is not accurate. It shows a value that is too high.
**Assess:** This is a reasonable answer—your speedometer is intended to give you a good estimate to your actual speed. Her speedometer is reading within 5% of the true value and rumor has it that the highway patrol will allow up to 10% on a good day. A well-calibrated speedometer could be this much off by changing the size of the tires.

**P1.65. Strategize:** Distance is the quantity measured by the odometer and depends on the path taken. The displacement is the difference between two locations, and is independent of the path taken between the two endpoints. The speed is the distance divided by the time interval.
**Prepare:** Knowing that speed is distance divided by time, the distance is the speed multiplied by the time. 15 min = ¼ h.
**Solve:**
**(a)** The distance traveled during the ¼ hour is

$$\text{distance} = \text{speed}\times\text{time} = (100\text{ km/h})(0.25\text{ h}) = 25\text{ km}$$

**(b)** Since the circumference of the track is 12.5 km, then the car goes completely around the track exactly twice in covering 25 km. Hence, the displacement from the initial position is 0 km.
**(c)** The speed of the car is

$$v = \left(100\frac{\text{km}}{\text{h}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 28\text{ m/s}$$

**Assess:** 28 m/s seems like a reasonable speed for a fast car.

**P1.66. Strategize:** This problem involves estimation, such that many answers are possible.
**Prepare:** Knowing the speed the signal travels (approximately 25 m/s) and estimating the distance from your brain to your hand to be about 1.0 m, we can determine the transmission time. Some unit conversion will be required to get the answer in ms.
**Solve:** The transmission time for the signal may be determined by

$$t = \frac{\text{distance}}{\text{speed}} = \left(\frac{1\text{ m}}{25\text{ m/s}}\right)\left(\frac{10^3\text{ ms}}{\text{s}}\right) = 40\text{ ms}$$

**Assess:** When you touch something very hot, it takes a fraction of a second to remove your hand. Keeping in mind, that in this case the signal must make a round trip, the answer, while very small, seems reasonable.

**P1.67. Strategize:** This is a straightforward application of the definition of speed.
**Prepare:** Knowing the distance and time to travel that distance, we can determine the speed. Since we lack detailed information about the flight, and knowing that the flight is made by a bird, it is conceivable that its actual path darted back and forth and maybe even backtracked at times. If that is the case its actual distance of travel and hence average speed would be larger.
**Solve:** **(a)** The minimum average speed of the albatross may be determined by

$$v = \frac{\text{distance}}{\text{time}} = \left(\frac{1.2\times10^3\text{ km}}{1.4\text{ day}}\right)\left(\frac{1\text{ day}}{24\text{ hr}}\right)\left(\frac{0.621\text{ mi}}{1\text{ km}}\right) = 22\text{ mph}$$

**(b)** The average speed of the bird is 22 mph if it flies in a straight line between the end points. If the bird deviates from this line, the average speed will have to be greater than 22 mph in order to have the 1200 km displacement in 1.4 days.
**Assess:** You can ride a bike 10 to 15 mph and while you are riding your bike, birds easily fly past you. In light of that this is a reasonable answer.

**P1.68. Strategize:** This question involves unit conversion and the definition of speed.
**Prepare:** We will need to convert to SI units throughout the problem.
**Solve: (a)** The length is given as $2\ \mu\text{m} = 2\times10^{-6}\ \text{m}$ (using the data from Table 1.2)
**(b)** The diameter is $1\ \mu\text{m} = 1\times10^{-6}\ \text{m}$ (using the data from Table 1.2)
**(c)** The mass is given as $1\times10^{-12}\ \text{g} = (1\times10^{-12}\ \text{g})(1\ \text{kg}/1000\ \text{g}) = 1\times10^{-15}\ \text{kg}$
**(d)** The length of the bacterium's DNA is given as 700 times longer than the bacterium's length. Therefore the length of DNA is $(700)(2\times10^{-6}\ \text{m}) = 1\times10^{-3}\ \text{m}$. We need to convert this to millimeters.

$$1\times10^{-3}\ \text{m} = 1\times10^{-3}\ \text{m}\left(\frac{1000\ \text{mm}}{1\ \text{m}}\right) = 1\ \text{mm}$$

**(e)** The organism travels at $20\ \mu\text{m/s}$. Assume this is given to two significant figures. Converting to m/s, $v = 20\ \mu\text{m/s} = 2.0\times10^{-5}\ \text{m/s}$.
A day is

$$1\ \text{day} = (1\ \text{day})\left(\frac{24\ \text{h}}{\text{d}}\right)\left(\frac{60\ \text{min}}{\text{h}}\right)\left(\frac{60\ \text{s}}{\text{min}}\right) = 86,400\ \text{s}$$

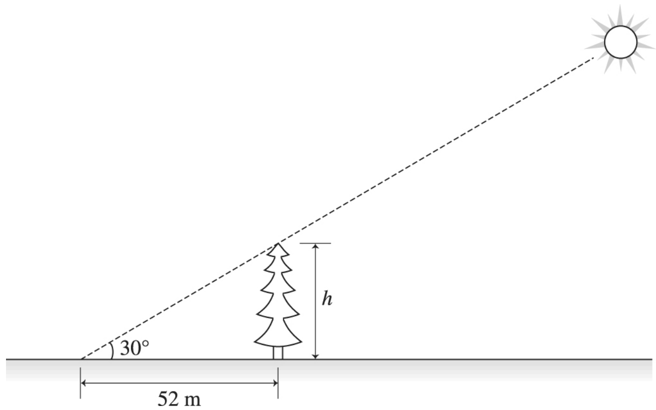
So the bacterium travels

$$\Delta x = v\Delta t = \left(2.0\times10^{-5}\ \frac{\text{m}}{\text{s}}\right)(86\ 400\ \text{s}) = 1.7\ \text{m}$$

**Assess:** Use the method of multiplying by one to help keep track of multiple unit conversions.

**P1.69. Strategize:** This problem involves displacement, which is the difference between initial and final positions. We also distinguish between speed and velocity. Since velocity has a direction associated with it, in order for two segments to describe the same velocity, they would need to be the same length and the same direction. For them to describe the same speed, they only need to have the same length (since time intervals are fixed).
**Prepare:** Assume that the bacterium moves along the path to consecutive letters.
**Solve: (a)** The displacements in segments AB and CD are the same (five right and one up). No other pairs appear to be the same.
**(b)** The problem explicitly stated that the bacteria move at a constant speed, so the answer is all of the segments.
**(c)** Since the displacements in segments AB and CD are the same (and the bacterium had the same speed in both segments, i.e., $\Delta t$ is the same for both segments), then the velocity is the same in those two segments. Since no other pairs of segments have the same direction, they can't have the same velocity.
**Assess:** Remember that both displacement and velocity are vectors, so the direction matters. Only the length (magnitude) matters with speed since it is a scalar.

**P1.70. Strategize:** We can relate vertical and horizontal distances to the given angle using trigonometry.
**Prepare:** The best way to prepare for this problem is to draw a diagram. In the triangle, the height $h$ of the tree that we want to know is the side opposite to the given angle.




**Solve:**

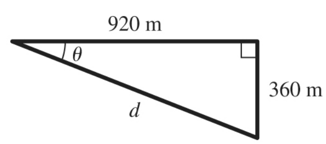
$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\text{opposite} = \text{adjacent} \times \tan\theta$$

$$h = 52 \text{ m} \times \tan 30° = 30 \text{ m}$$

**Assess:** The shadow is longer than the height of the tree because the sun is low in the sky.

**P1.71. Strategize:** We can relate the distances given to the angle using trigonometry.
**Prepare:** Draw a diagram of the situation. Note the right triangle.




**Solve:** Use knowledge about right triangles from trigonometry.
**(a)** The angle of the path below the horizontal is

$$\theta = \arctan\left(\frac{360 \text{ m}}{920 \text{ m}}\right) = 21°$$

**(b)** The distance $d$ covered is

$$d = \sqrt{(360 \text{ m})^2 + (920 \text{ m})^2} = 988 \text{ m}$$

which should be reported as 990 m to two significant figures. We keep one more significant figure to use in the next step.
**(c)** The seal's speed is

$$v = \frac{\text{distance}}{\text{time}} = \left(\frac{988 \text{ m}}{4.0 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right) = 4.1 \text{ m/s}$$

**Assess:** Because the seal descended less than the horizontal distance we expect the angle to be less than 45 degrees.

**P1.72. Strategize:** This problem involves a displacement with components in two orthogonal directions. We will call east the $+x$ axis and north the $+y$ direction.

**Prepare:** Erica's displacement 25° north of east (which we will call $d_1$) has both an $x$ component and a $y$ component, but the second leg (which we will call $d_2$) has only a $y$ component. We must determine the displacement in each orthogonal direction, and then use the Pythagorean Theorem to combine them and find the straight-line distance.

**Solve:** For the total displacement eastward, we have

$$\Delta x = d_1 \cos(\theta) = (5.2 \text{ mi})\cos(25°) = 4.71 \text{ mi}$$

And for the displacement northward, we have

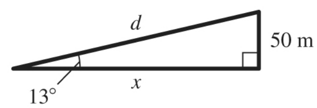
$$\Delta y = d_1 \sin(\theta) + d_2 = (5.2 \text{ mi})\sin(25°) + (4.0 \text{ mi}) = 6.20 \text{ mi}$$

The total straight-line distance is given by

$$d = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(4.71\text{mi})^2 + (6.20 \text{ mi})^2} = 7.8 \text{ mi}$$

**Assess:** This is a reasonable distance. Note that this is less than the sum of the distances of the two legs, which it should be.

**P1.73. Strategize:** We can relate the given distance and angle to the required distance using trigonometry.
**Prepare:** Draw a diagram of the situation. Note the right triangle.




**Solve:** Use knowledge about right triangles from trigonometry.
**(a)** The horizontal distance $x$ is

$$x = \frac{50 \text{ m}}{\tan 13°} = 216.6 \text{ m}$$

This should be reported as 220 m to two significant figures.
**(b)** The distance $d$ covered is

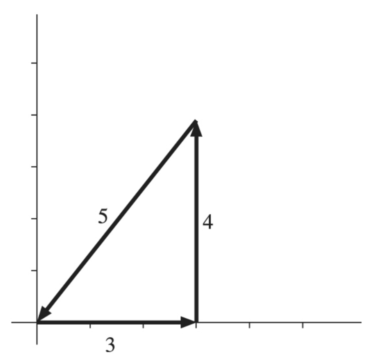
$$d = \sqrt{(50 \text{ m})^2 + (216.6 \text{ m})^2} = 222.3 \text{ m}$$

which should be reported as 220 m to two significant figures. We keep two more significant figures to use in the next step.
**(c)** The time it takes the shark is

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \left(\frac{222.3 \text{ m}}{0.85 \text{ m/s}}\right) = 260 \text{ s}$$

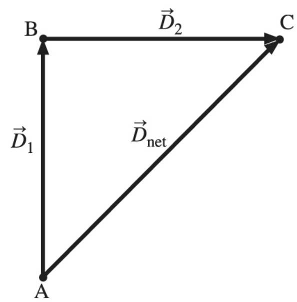
**Assess:** 260 s is just over 4 min, which is impressive but reasonable.

**P1.74. Strategize:** Because the directions of motion are orthogonal, we can use the Pythagorean Theorem to add the two displacements.
**Prepare:** Draw a right triangle with legs of length 3 and 4. The hypotenuse will have a length of 5. While we are given the time of flight for the legs, we are not actually told what the speed is, so we don't really know the exact distance, but since the speed is constant we know the ratios of the sides of the triangle are as given.




**Solve:** The bird will fly for $3.0 \text{ min} + 4.0 \text{ min} + 5.0 \text{ min} = 12.0 \text{ min}$.
**Assess:** The diagram explains everything. The third side of the triangle is less than the sum of the first two sides.

**P1.75. Strategize:** We can relate the speed to the displacement, easily. The two legs of the displacement are in orthogonal directions, such that we can use the Pythagorean Theorem.
**Prepare:** Since during part of the motion John is traveling north and then turns east, the rules of vector addition will be used to determine the net displacement.
**Solve: (a)** The vectors form a right triangle. See the following vector diagram.




The length of the net displacement vector is

$$\overline{AC} = \sqrt{\overline{AB}^2 + \overline{BC}^2} = \sqrt{(1.00\text{ km})^2 + (1.00\text{ km})^2} = 1.41\text{ km}$$

**(b)** Jane walks along John's net displacement vector, so she only travels 1.41 km, while John travels a total distance of 2.00 km. Since he travels at 1.50 m/s during the entire stroll, the time John takes to get to his destination is

$$\Delta t_{\text{John}} = \frac{2000\text{ m}}{1.50\text{ m/s}} = 1.33\times 10^3\text{s}$$

For Jane to walk 1.41 km in this time, her velocity would need to be

$$v_{\text{Jane}} = \frac{1410\text{ m}}{1.33\times 10^3\text{ s}} = 1.06\text{ m/s}$$

**Assess:** Jane must walk slower than John to walk the shorter distance in the same time, so the answer makes sense. For displacements in different directions you must use the law of vector addition.

**P1.76. Strategize:** This is a simple calculation of growth speed, given the change in height and the time interval.
**Prepare:** Assume that the growth is steady, at least for the first three years.
We will subtract any two heights and divide by the corresponding time interval.
**Solve:**

$$v = \frac{30\text{ ft} - 12\text{ ft}}{3\text{ yr} - 1\text{ yr}} = \frac{18\text{ ft}}{2\text{ yr}} = 9\frac{\text{ft}}{\text{yr}}$$

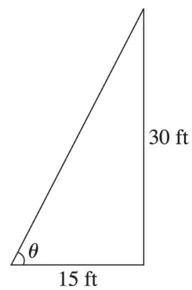
So the correct answer is B.
**Assess:** You should get the same answer by choosing other values, such as year 2 and year 1. Try it.

**P1.77. Strategize:** This is a simple unit conversion problem.
**Prepare:** We must convert ft/yr to m/s.
**Solve:** The tree grows at 9 ft/yr, so

$$9\frac{\text{ft}}{\text{yr}} = \left(\frac{9\text{ ft}}{\text{yr}}\right)\left(\frac{0.305\text{ m}}{1\text{ ft}}\right)\left(\frac{1\text{ yr}}{365\text{ days}}\right)\left(\frac{1\text{ day}}{24\text{ h}}\right)\left(\frac{1\text{ h}}{60\text{ min}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 9\times 10^{-8}\text{ m/s}$$

The correct answer is A.
**Assess:** Use the method of multiplying by one to keep track of conversion factors.

**P1.78. Strategize:** Since we are given the vertical height of the tree and the horizontal distance from the tree, we have a right triangle and can use trigonometry.
**Prepare:** Draw a diagram and label the sides and the angle you want to know.




**Solve:**

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

$$\theta = \tan^{-1}\left(\frac{\text{opposite}}{\text{adjacent}}\right) = \tan^{-1}\left(\frac{30\text{ ft}}{15\text{ ft}}\right) = 63°$$

The correct answer is A.
**Assess:** Imagine holding your protractor to your diagram and convince yourself that 63° is in the right ballpark.