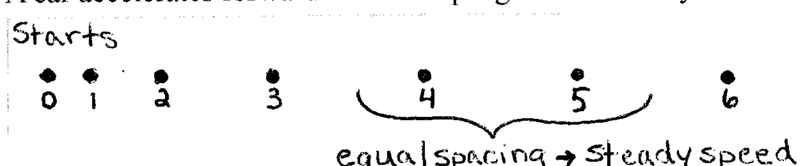
1 Concepts of Motion and Mathematical Background

1.1 Motion: A First Look

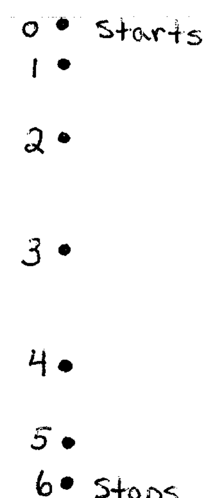
Exercises 1–5: Draw a motion diagram for each motion described below.

- Use the particle model to represent the object as a particle.
- Six to eight dots are appropriate for most motion diagrams.
- Number the positions in order, as shown in Figure 1.4 in the text.
- Be neat and accurate!

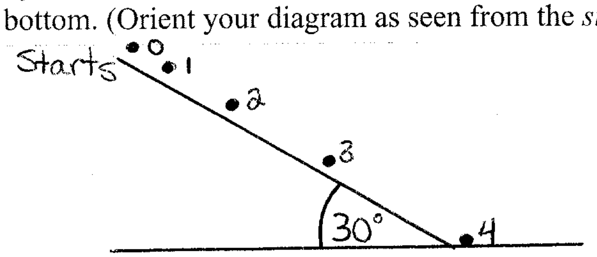
1. A car accelerates forward from a stop sign. It eventually reaches a steady speed of 45 mph.



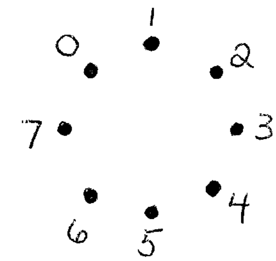
2. An elevator starts from rest at the 100th floor of the Empire State Building and descends, with no stops, until coming to rest on the ground floor. (Draw this one *vertically* since the motion is vertical.)



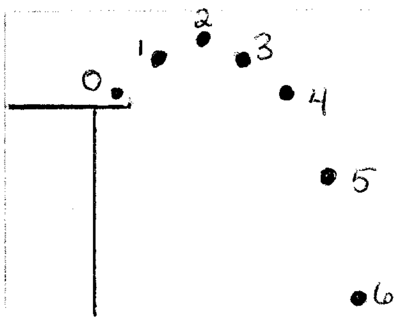
3. A skier starts *from rest* at the top of a 30° snow-covered slope and steadily speeds up as she skis to the bottom. (Orient your diagram as seen from the *side*. Label the 30° angle.)



4. The space shuttle orbits the earth in a circular orbit, completing one revolution in 90 minutes.

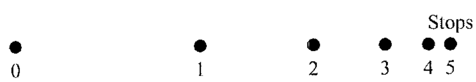


5. Bob throws a ball at an upward 45° angle from a third-story balcony. The ball lands on the ground below.



Exercises 6–9: For each motion diagram, write a short description of the motion of an object that will match the diagram. Your descriptions should name *specific* objects and be phrased similarly to the descriptions of Exercises 1 to 5. Note the axis labels on Exercises 8 and 9.

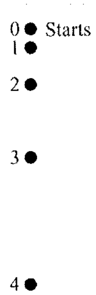
6.



A car brakes to a stop from a speed of 40 km/hr.

(Any linear motion of an object slowing down to a stop.)

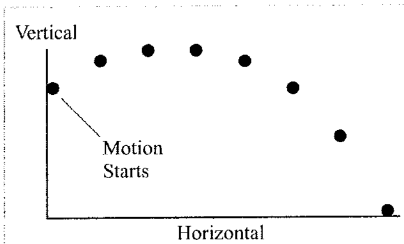
7.



Mikey drops a rock off of a cliff.

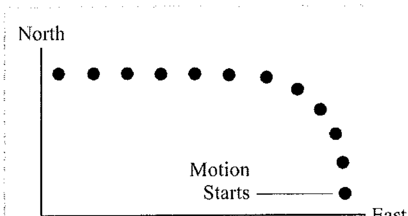
(Any downward acceleration from rest.)

8.



Sally launches a water balloon from her second-floor window in an attempt to hit her ex-boyfriend. (projectile motion)

9.

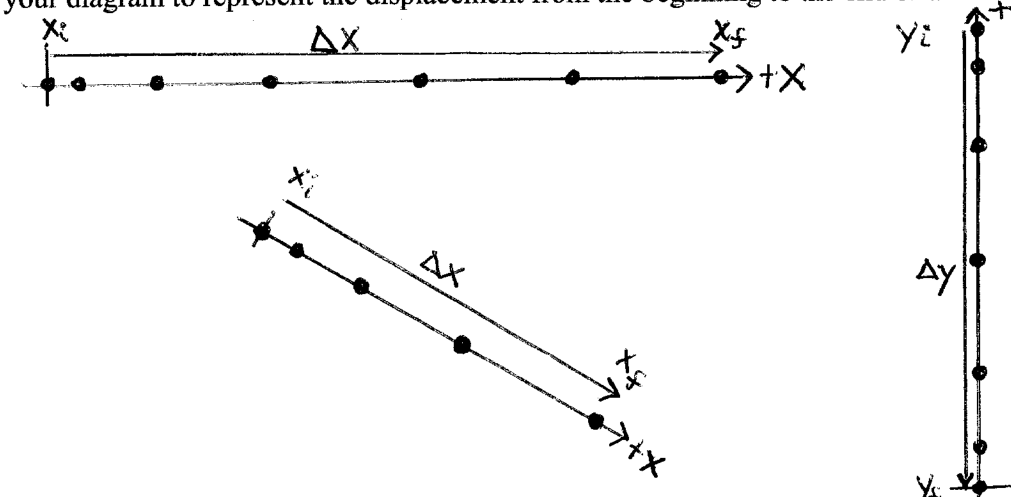


A man walks steadily along a path that turns from north towards the west and continues directly west.

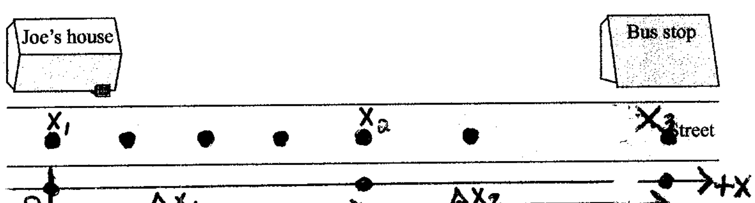
(Any turning from north to west at constant speed.)

1.2 Position and Time: Putting Numbers on Nature

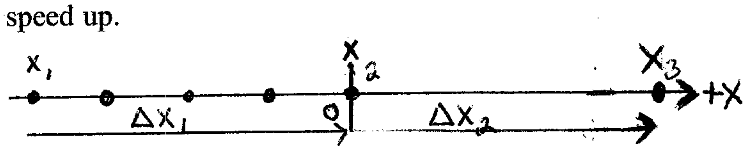
10. Redraw each of the motion diagrams from Exercises 1 to 3 in the space below. Add a coordinate axis to each drawing and label the initial and final positions. Draw an arrow on your diagram to represent the displacement from the beginning to the end of the motion.



11. In the picture below Joe starts walking casually at constant speed from his house on Main Street to the bus stop 200 m down the street. When he is halfway there, he sees the bus and steadily speeds up until he reaches the bus stop.
   a. Draw a motion diagram in the street of the picture to represent Joe's motion.
   b. Add a coordinate axis below your diagram with Joe's house as the origin. Label Joe's initial position at the start of his walk as x_1, his position when he sees the bus as x_2, and his final position when he arrives at the bus stop as x_3. Draw arrows above the coordinate axis to represent Joe's displacement from his initial position to his position when he first sees the bus and the displacement from where he sees the bus to the bus stop. Label these displacements Δx_1 and Δx_2, respectively.



   c. Repeat part b in the space below but with the origin at the location where Joe starts to speed up.



   d. How do the displacement arrows change when you change the location of the origin?

They do not change. The displacement arrows are independent of the choice of origin.

1.3 Velocity

12. A moth flies a distance of 3 m in only one-third of a second.

a. What does the ratio 3/(1/3) tell you about the moth's motion? Explain.

It tells the distance traveled (3m) in the given time interval ($\frac{1}{3}$s) divided by that time interval.

$3\text{m in } 1/3\text{s} = 3\text{m}/(1/3\text{s}) = 9\text{m/s}$

b. What does the ratio (1/3)/3 tell you about the moth's motion?

It took 1/3s for the moth to travel 3m, so this is the time required for a given distance divided by that distance.

$1/3\text{s to travel } 3\text{m} = 1/3\text{s}/3\text{m} = 1\text{s}/9\text{m} = \frac{1}{9}\frac{\text{s}}{\text{m}}$

c. How far would the moth fly in one tenth of a second?

$$\frac{3\text{m}}{(1/3\text{s})} \times \frac{1}{10}\text{s} = 0.9\text{m}$$

d. How long does it take the moth to fly 4 m?

$$\left(1/3\text{s}/3\text{m}\right) \times 4\text{m} = \frac{4}{9}\text{s}$$

13. a. If someone drives at 25 miles per hour, is it necessary that they do so for an hour?

No. The speed is a ratio of distance traveled in a time interval, but the units do not specify the time traveled or the distance traveled. Speed only specifies the ratio of these two quantities.

b. Is it necessary to have a cubic centimeter of gold to say that gold has a density of 19.3 grams per cubic centimeter? Explain.

No. The density of a substance is a measure of mass per unit volume, but the density is a ratio of mass to volume and does not require a specific mass or specific volume.

1.4 A Sense of Scale: Significant Figures, Scientific Notation, and Units

14. How many significant figures does each of the following numbers have?

a. 6.21 3	e. 0.0621 3	i. 1.0621 5
b. 62.1 3	f. 0.620 3	j. 6.21×10^3 3
c. 6210 3	g. 0.62 2	k. 6.21×10^{-3} 3
d. 6210.0 5	h. .62 2	l. 62.1×10^3 3

15. Compute the following numbers, applying the significant figure standards adopted for this text.

a. $33.3 \times 25.4 =$ 8.46×10^2	e. $2.345 \times 3.321 =$ 7.788
b. $33.3 - 25.4 =$ 7.9	f. $(4.32 \times 1.23) - 5.1 =$ $2. \times 10^{-1}$
c. $33.3 \div 45.1 =$ 7.38×10^{-1}	g. $33.3^2 =$ 1.11×10^3
d. $33.3 \times 45.1 =$ 1.50×10^3	h. $\sqrt{33.3} =$ 5.77

16. Express the following numbers and computed results in scientific notation, paying attention to significant figures.

a. 9,827 = 9.827×10^3	d. $32{,}014 \times 47 =$ 1.5×10^6
b. 0.000000550 = 5.50×10^{-7}	e. $0.059 \div 2{,}304 =$ 2.6×10^{-5}
c. 3,200,000 = 3.2×10^6	f. $320. \times 0.050 =$ 1.6×10^1

17. Convert the following to SI units. Work across the line and show all steps in the conversion. Use scientific notation and apply the proper use of significant figures. **Note:** Think carefully about g and h. A picture may help.

a. $9.12\ \mu s \times \frac{10^{-6} s}{1 \mu s} = 9.12 \times 10^{-6} s$

b. $3.42\ km \times \frac{10^3 m}{1\ km} = 3.42 \times 10^3 m$

c. $44\ cm/ms \times \frac{10^{-2} m}{1\ cm} \times \frac{10^3 ms}{1 s} = 4.4 \times 10^2 \frac{m}{s}$

d. $80\ km/hr \times \frac{10^3 m}{1\ km} \times \frac{1\ hr}{60\ min} \times \frac{1\ min}{60 s} = 22 \frac{m}{s}$

e. $60\ mph \times \frac{5280 ft}{1\ mi} \times \frac{12 in}{1 ft} \times \frac{2.54 cm}{1 in} \times \frac{10^{-2} m}{1 cm} \times \frac{1 hr}{3600 s} = 27 \frac{m}{s}$

f. $8\ in \times \frac{2.54 cm}{1 in} \times \frac{10^{-2} m}{1 cm} = 2 \times 10^{-1} m$

g. $14\ in^2 \times \frac{2.54 cm}{1 in} \times \frac{2.54 cm}{1 in} \times \frac{10^{-2} m}{1 cm} \times \frac{10^{-2} m}{1 cm} = 9.0 \times 10^{-3} m^2$

h. $250\ cm^3 \times \frac{10^{-2} m}{1 cm} \times \frac{10^{-2} m}{1 cm} \times \frac{10^{-2} m}{1 cm} = 2.5 \times 10^{-4} m^3$

18. Use Tables 1.4 and 1.5 and Examples 1.2 and 1.3 to assess whether or not the following statements are *reasonable.*

a. Joe is 180 cm tall.

$180\,cm = 18 \times 10\,cm \approx 18 \times 4\,in = 72\,in = 6\,ft$

Reasonable

b. I rode my bike to campus at a speed of 50 m/s.

$50 \times 1\,m/s \approx 50 \times 2\,mph = 100\,mph$

Not Reasonable

c. A skier reaches the bottom of the hill going 25 m/s.

$25 \times 1\,m/s \approx 25 \times 2\,mph = 50\,mph$

Reasonable

(downhill racers reach ~85 mph)

d. I can throw a ball a distance of 2 km.

$2\,km \sim 1.2\,miles$

Not Reasonable

e. I can throw a ball at a speed of 50 km/hr.

$50\,\frac{km}{hr} \sim 30\,mph$

Reasonable

(major league pitchers throw at ~100 mph)

f. Joan's newborn baby has a mass of 33 kg.

$33\,kg \times \frac{2.2\,lb}{1\,kg} = 73.\,lb$

Not Reasonable

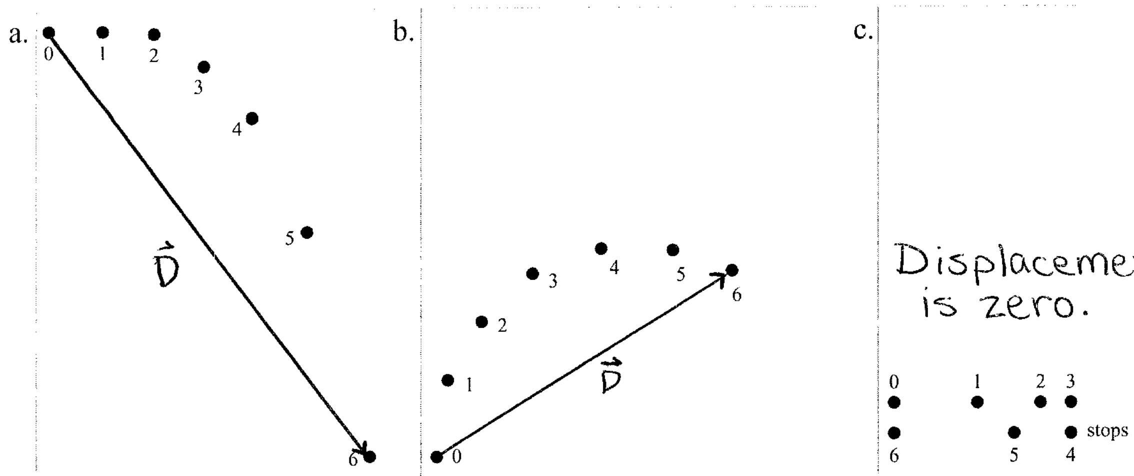
g. A typical hummingbird has a mass of 3.3 g.

$3.3\,g \times \frac{1\,kg}{1000\,g} \times \frac{2.2\,lb}{1\,kg} \times \frac{16\,oz}{1\,lb} = .12\,oz$

Reasonable! (or, perhaps, surprising)

1.5 Vectors and Motion: A First Look

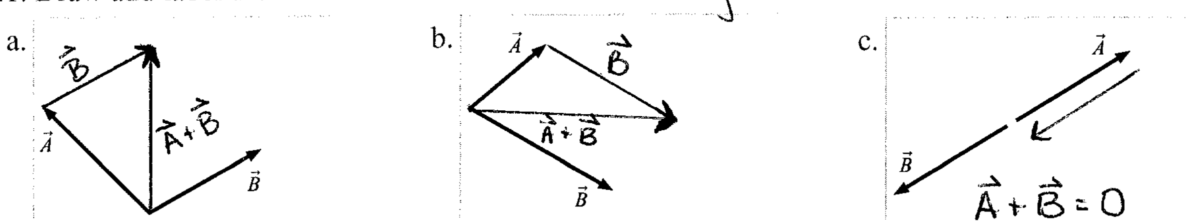
19. For the following motion diagrams, draw an arrow to indicate the displacement vector between the initial and final positions.



20. In Exercise 19, is the object's displacement equal to the distance the object travels? Explain.

No, the magnitude of the displacement is always less than or equal to the distance traveled. Displacement includes direction and is equal in magnitude to distance traveled only if the motion is in one direction in a straight line.

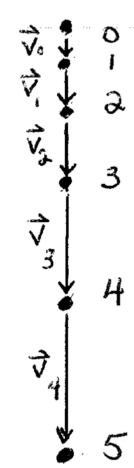
21. Draw and label the vector sum $\vec{A} + \vec{B}$.



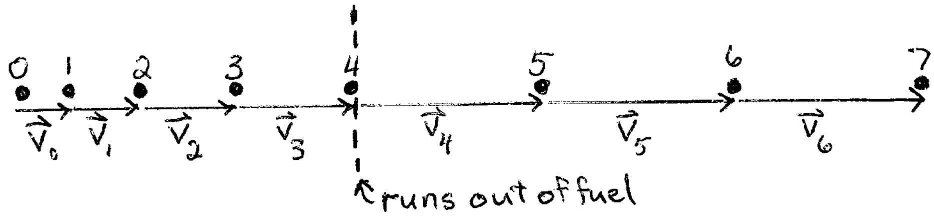
Exercises 22–26: Draw a motion diagram for each motion described below.

- Use the particle model.
- Show and label the *velocity* vectors.

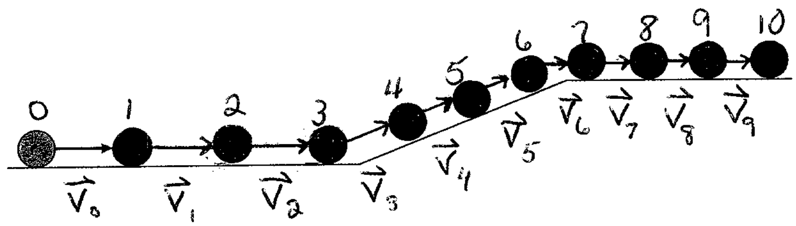
22. Galileo drops a ball from the Leaning Tower of Pisa. Consider the ball's motion from the moment it leaves his hand until a microsecond before it hits the ground. Your diagram should be vertical.



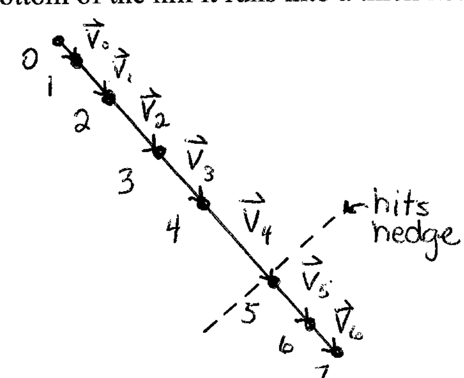
23. A rocket-powered car on a test track accelerates from rest to a high speed, then coasts at constant speed after running out of fuel. Draw a dotted line across your diagram to indicate the point at which the car runs out of fuel.



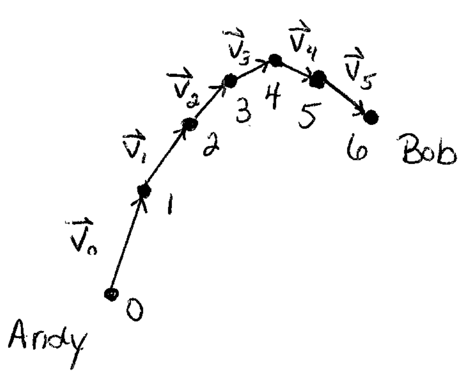
24. A bowling ball being returned from the pin area to the bowler starts out rolling at a constant speed. It then goes up a ramp and exits onto a level section at very low speed. You'll need 10 or 12 points to indicate the motion clearly.



25. A car is parked on a hill. The brakes fail, and the car rolls down the hill with an ever-increasing speed. At the bottom of the hill it runs into a thick hedge and gently comes to a halt.



26. Andy is standing on the street. Bob is standing on the second-floor balcony of their apartment, about 30 feet back from the street. Andy throws a baseball to Bob. Consider the ball's motion from the moment it leaves Andy's hand until a microsecond before Bob catches it.



1.6 Making Models: The Power of Physics

27. One of the difficulties some students have in beginning physics is with the use of algebra involving unfamiliar symbols. As a warmup for what's to come, algebraically solve the following equations for the specified variables in terms of the other symbols given:

a. Solve for t: $v = v_0 + at$

$v - v_0 = at$

$\frac{v-v_0}{a} = t$

b. Solve for x: $t = \left(\frac{2x}{a}\right)^{1/2}$

$t^2 = \frac{2x}{a}$

$\frac{at^2}{2} = x$

c. Solve for s: $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$\frac{1}{s} = \frac{1}{f} - \frac{1}{s'}$

$\frac{1}{s} = \frac{s'-f}{fs'}$ so $\left[\frac{1}{s} = \frac{s'-f}{fs'}\right]^{-1} \Rightarrow s = \frac{fs'}{s'-f}$

d. Eliminate T from the two equations and solve for a:

$T - m_1 g = m_1 a \Rightarrow T = m_1 a + m_1 g$

$m_2 g - T = m_2 a$

$m_2 g - (m_1 a + m_1 g) = m_2 a$

$m_2 g - m_1 a - m_1 g = m_2 a$

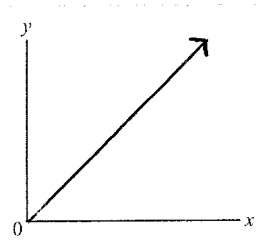
$m_2 g - m_1 g = m_2 a + m_1 a$

$(m_2 - m_1) g = a(m_2 + m_1)$

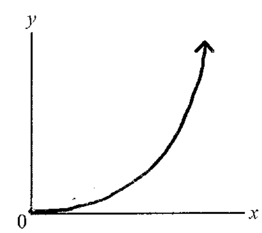
$a = (m_2 - m_1) g / (m_2 + m_1)$

28. On the axes below, sketch a graph of y versus x if y is given by the equation shown. Assume that m and b are both positive numbers. The goal is to sketch a graph with the proper *shape*.

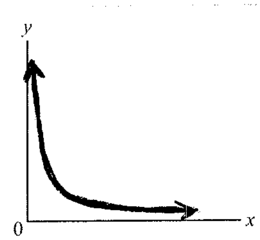
a. $y = mx + b$



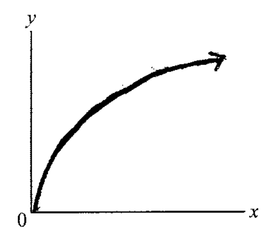
b. $y = mx^2$



c. $y = m/x^2$



d. $y^2 = mx$



1.7 Where Do We Go from Here?

No exercises for this section.