1

MODELS, MEASUREMENTS, AND VECTORS

Answers to Multiple-Choice Problems

1. B **2.** A **3.** A **4.** B **5.** A **6.** C **7.** C **8.** C **9.** B **10.** D

Solutions to Problems

1.1. Set Up: From the meaning of the metric prefixes we know: $1\text{ megaohm} = 1\text{ M}\Omega = 10^6$ ohms; 1 picofarad = 1 pF = 10^{-12} farad; $1\text{ gigameter} = 1\text{ Gm} = 10^9$ m; $1\text{ nanometer} = 1\text{ nm} = 10^{-9}$ m; and $1\text{ femtometer} = 1\text{ fm} = 10^{-15}$ m.

Solve: (a) $(7.85\text{ megohms})\left(\dfrac{10^6\text{ ohms}}{1\text{ megaohm}}\right) = 7.85\times10^6\text{ ohms}$

(b) $(5\text{ picofarads})\left(\dfrac{10^{-12}\text{ farad}}{1\text{ picofarad}}\right) = 5\times10^{-12}\text{ picofarad}$

(c) $(3.00\times10^8\text{ m/s})\left(\dfrac{1\text{ gigameter}}{10^9\text{ m}}\right) = 0.300\text{ gigameter/s}$

(d) $(400\text{ nm})\left(\dfrac{10^{-9}\text{ m}}{1\text{ nm}}\right) = 4.00\times10^{-7}\text{ m};\ \ (700\text{ nm})\left(\dfrac{10^{-9}\text{ m}}{1\text{ nm}}\right) = 7.00\times10^{-7}\text{ m}$

(e) $(2\text{ femtometer})\left(\dfrac{10^{-15}\text{ m}}{1\text{ femtometer}}\right) = 2\times10^{-15}\text{ m}$

1.2. Set Up: We know the equalities: $1\text{ mg} = 10^{-3}$ g, $1\ \mu\text{g} = 10^{-6}$ g, and $1\text{ kg} = 10^3$ g.

Solve: (a) $(410\text{ mg/day})\left(\dfrac{10^{-3}\text{ g}}{1\text{ mg}}\right)\left(\dfrac{1\ \mu\text{g}}{10^{-6}\text{ g}}\right) = 4.10\times10^5\ \mu\text{g/day}$

(b) $(12\text{ mg/kg})(75\text{ kg}) = (900\text{ mg})\left(\dfrac{10^{-3}\text{ g}}{1\text{ mg}}\right) = 0.900\text{ g}$

(c) The mass of each tablet is

$$(2.0\text{ mg})\left(\frac{10^{-3}\text{ g}}{1\text{ mg}}\right) = 2.0\times10^{-3}\text{ g}$$

The number of tablets required each day is the number of grams recommended per day divided by the number of grams per tablet:

$$\frac{0.0030 \text{ g/day}}{2.0\times10^{-3} \text{ g/tablet}} = 1.5 \text{ tablet/day}$$

Take two tablets each day.

(d) $(0.000070 \text{ g/day})\left(\frac{1 \text{ mg}}{10^{-3} \text{ g}}\right) = 0.070 \text{ mg/day}$

1.3. Set Up: In part (a), we need to solve an equation of the form

$$\left(\frac{2.54 \text{ cm}}{1.00 \text{ in.}}\right)x(1.0 \text{ mi}) = y$$

where x is a series of conversion equalities and y is the unknown number of kilometers. For part (b), we must prove $(1.00 \text{ mL})x = 1.00 \text{ cm}^3$ using the equalities $1 \text{ L} = 1000 \text{ cm}^3$ and $10^3 \text{ mL} = 1 \text{ L}$. Part (c) requires the application of the equality $1 \text{ mL} = 1 \text{ cm}^3$.

Solve: (a) $\left[\left(\frac{2.54 \text{ cm}}{1.00 \text{ in.}}\right)\left(\frac{12.0 \text{ in.}}{1.00 \text{ ft}}\right)\left(\frac{5280 \text{ ft}}{1.00 \text{ mi}}\right)\right](1.00 \text{ mi})\left[\left(\frac{1.00 \text{ m}}{100 \text{ cm}}\right)\left(\frac{1.00 \text{ km}}{10^3 \text{ m}}\right)\right] = y;\quad y = 1.61 \text{ km}$

(b) $(1.00 \text{ mL})\left(\frac{1.00 \text{ L}}{10^3 \text{ mL}}\right)\left(\frac{1000 \text{ cm}^3}{1.00 \text{ L}}\right) = 1.00 \text{ cm}^3$

(c) $(1.00 \text{ L})\left(\frac{10^3 \text{ mL}}{1.00 \text{ L}}\right)\left(\frac{1.00 \text{ cm}^3}{1.00 \text{ mL}}\right) = 1000 \text{ cm}^3$

***1.4. Set Up:** We need to apply the following conversion equalities: $1000 \text{ g} = 1.00 \text{ kg}$, $100 \text{ cm} = 1.00 \text{ m}$, and $1.00 \text{ L} = 1000 \text{ cm}^3$.

Solve: (a) $(1.00 \text{ g/cm}^3)\left(\frac{1.00 \text{ kg}}{1000 \text{ g}}\right)\left(\frac{100 \text{ cm}}{1.00 \text{ m}}\right)^3 = 1000 \text{ kg/m}^3$

(b) $(1050 \text{ kg/m}^3)\left(\frac{1000 \text{ g}}{1.00 \text{ kg}}\right)\left(\frac{1.00 \text{ m}}{1000 \text{ cm}}\right)^3 = 1.05 \text{ g/cm}^3$

(c) $(1.00 \text{ L})\left(\frac{1000 \text{ cm}^3}{1.00 \text{ L}}\right)\left(\frac{1.00 \text{ g}}{1.00 \text{ cm}^3}\right)\left(\frac{1.00 \text{ kg}}{1000 \text{ g}}\right) = 1.00 \text{ kg};\quad (1.00 \text{ kg})\left(\frac{2.205 \text{ lb}}{1.00 \text{ kg}}\right) = 2.20 \text{ lb}$

Reflect: We could express the density of water as 1.00 kg/L.

1.5. Set Up: From the appendices we find the conversion from kilometers into miles, and the radius and period of the earth's orbit: $1 \text{ km} = 0.6214 \text{ mi}$; $r = 1.50\times10^{11} \text{ m}$; $T = 365.3$ days. Since the earth's orbit is nearly circular, its circumference is $C = 2\pi r$.

Solve:

$$\begin{aligned}
\text{speed} &= \frac{\text{distance}}{\text{time}} \\
&= \left(\frac{2\pi(1.50\times10^{11} \text{ m})}{365.3 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ h}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = 2.99\times10^4 \text{ m/s} \\
&= \left(\frac{2\pi(1.50\times10^{11} \text{ m})}{365.3 \text{ days}}\right)\left(\frac{1 \text{ day}}{24 \text{ h}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = \underline{1.07}5\times10^5 \text{ km/h} = 1.08\times10^5 \text{ km/h} \\
&= (\underline{1.07}5\times10^5 \text{ km/h})\left(\frac{0.6214 \text{ mi}}{1 \text{ km}}\right) = 6.68\times10^4 \text{ mi/h}
\end{aligned}$$

Reflect: To minimize rounding errors, we should avoid rounding in intermediate calculations: this is why we used $\underline{1.07}5\times10^5$ km/h rather than 1.08×10^5 km/h to calculate our final answer. The significant digits are underlined.

1.6. Set Up: The speed of light is $v = 3.00\times10^8$ m/s; 1 ft = 0.3048 m; 1 s = 10^9 ns; $t = d/v$.

Solve: $t = \dfrac{0.3048\text{ m}}{3.00\times10^8\text{ m/s}} = 1.02\times10^{-9}\text{ s} = 1.02\text{ ns}$

Reflect: In 1.00 s light travels $3.00\times10^8\text{ m} = 3.00\times10^5\text{ km} = 1.86\times10^5\text{ mi}$.

***1.7. Set Up:** We apply the equalities of 1 km = 0.6214 mi and 1 gal = 3.788 L.

Solve: $(37.5\text{ mi/gal})\left(\dfrac{1\text{ km}}{0.6214\text{ mi}}\right)\left(\dfrac{1\text{ gal}}{3.788\text{ L}}\right) = 15.9\text{ km/L}$

Reflect: Note how the unit conversion strategy, of cancellation of units, automatically tells us whether to multiply or divide by the conversion factor.

1.8. Set Up: Apply the given conversion factors, 1 furlong = 0.1250 mi and 1 fortnight = 14 days, along with 1 day = 24 h.

Solve: $(180{,}000\text{ furlongs/fortnight})\left(\dfrac{0.125\text{ mi}}{1\text{ furlong}}\right)\left(\dfrac{1\text{ fortnight}}{14\text{ days}}\right)\left(\dfrac{1\text{ day}}{24\text{ h}}\right) = 67\text{ mi/h}$

1.9. Set Up: We know 1 euro = \$1.25 and 1 gal = 3.788 L.

Solve: $(1.35\text{ euros/L})\left(\dfrac{\$1.25}{1\text{ euro}}\right)\left(\dfrac{3.788\text{ L}}{1\text{ gal}}\right) = \$6.39$ per gallon. Currently, in 2005, gasoline in the U.S. costs about \$2 per gallon so the price in Europe is about three times higher.

1.10. Set Up: From Appendix A, the volume V of a sphere is given in terms of its radius as $V = \dfrac{4}{3}\pi r^3$ while its surface area A is given as $A = 4\pi r^2$. Also, by definition, the radius is one-half the diameter or $r = d/2 = 1.0\ \mu$m. Finally, the necessary equalities for this problem are: $1\ \mu\text{m} = 10^{-6}$ m; $1\text{ cm} = 10^{-2}$ m; and $1\text{ mm} = 10^{-3}$ m.

Solve: $V = \dfrac{4}{3}\pi r^3 = \dfrac{4}{3}\pi(1.0\ \mu\text{m})^3\left(\dfrac{10^{-6}\text{ m}}{1\ \mu\text{m}}\right)^3\left(\dfrac{1\text{ cm}}{10^{-2}\text{ m}}\right)^3 = 4.2\times10^{-12}\text{ cm}^3$

and

$$A = 4\pi r^2 = 4\pi(1.0\ \mu\text{m})^2\left(\frac{10^{-6}\text{ m}}{1\ \mu\text{m}}\right)^2\left(\frac{1\text{ mm}}{10^{-3}\text{ m}}\right)^2 = 1.3\times10^{-5}\text{ mm}^2$$

***1.11. Set Up:** We apply the basic time relations of 1 h = 60 min and 1 min = 60 s in part (a) and use the result of (a) in part (b). Similarly, apply the result of part (b) in solving part (c).

Solve: (a) $(1\text{ h})\left(\dfrac{60\text{ min}}{1\text{ h}}\right)\left(\dfrac{60\text{ s}}{1\text{ min}}\right) = 3600\text{ s}$

(b) $(24\text{ h/day})\left[(3600\text{ s})/(1\text{ h})\right] = 86.4\times10^3\text{ s/day}$

(c) $(365\text{ day/year})[(86.4\times10^3\text{ s})/(1\text{ day})] = 31{,}536{,}000\text{ s/year} = 3.15\times10^7\text{ s/year}$

1.12. Set Up: (a) The appropriate equalities required are: 1 mi = 1609 m; 1 h = 3600 s; 1 mph = 0.4470 m/s; 1 ft = 0.3048 m; and 1 mi = 5280 ft.

Solve: **(a)** $(3.00\times10^8\ \text{m/s})\left(\dfrac{1\ \text{mi}}{1609\ \text{m}}\right)=1.86\times10^5\ \text{mi/s};\ (3.00\times10^8\ \text{m/s})\left(\dfrac{1\ \text{mi}}{1609\ \text{m}}\right)\left(\dfrac{3600\ \text{s}}{1\ \text{h}}\right)=6.71\times10^8\ \text{mph}$

(b) $(1100\ \text{ft/s})\left(\dfrac{0.3048\ \text{m}}{1\ \text{ft}}\right)=335\ \text{m/s};\ (1100\ \text{ft/s})\left(\dfrac{1\ \text{mi}}{5280\ \text{ft}}\right)\left(\dfrac{3600\ \text{s}}{1\ \text{h}}\right)=750\ \text{mph}$

(c) $(60\ \text{mi/h})\left(\dfrac{5280\ \text{ft}}{1\ \text{mi}}\right)\left(\dfrac{1\ \text{h}}{3600\text{s}}\right)=88\ \text{ft/s}$

(d) $(9.8\ \text{m/s}^2)\left(\dfrac{1\ \text{ft}}{0.3048\ \text{m}}\right)=32\ \text{ft/s}^2$

1.13. Set Up: In each case, round the last significant figure.
Solve: **(a)** 3.14, 3.1416, 3.1415927; **(b)** 2.72, 2.7183, 2.7182818; **(c)** 3.61, 3.6056, 3.6055513
Reflect: All of these representations of the quantities are imprecise, but become more precise as additional significant figures are retained.

1.14. Set Up: Use a calculator to calculate the decimal equivalent of each fraction and then round the numeral to the specified number of significant figures. Compare to π rounded to the same number of significant figures.
Solve: **(a)** 3.14286; **(b)** 3.14159; **(c)** The exact value of π rounded to six significant figures is 3.14159. Since the fraction 22/7 differs in the fourth significant figure, it is accurate to only three significant figures. The fraction 355/113 and π agree when expressed to six figures and thus agree to this precision.

1.15. Set Up: We know the relations: mass = density × volume; g and $1.00\ \text{L}=1.00\times10^3\ \text{cm}^3$.

Solve: ***Water:*** $m=(1.00\ \text{g/cm}^3)(1.00\times10^3\ \text{cm}^3)=1.00\times10^3\ \text{g}$

Blood: $m=(1.05\ \text{g/cm}^3)(1.00\times10^3\ \text{cm}^3)=1.05\times10^3\ \text{g}$

Seawater: $m=(1.03\ \text{g/cm}^3)(1.00\times10^3\ \text{cm}^3)=1.03\times10^3\ \text{g}$

***1.16. Set Up:** We are given the relation density = mass/volume = m/V, where $V=\frac{4}{3}\pi r^3$ for a sphere. From Appendix F, the earth has mass of $m=5.97\times10^{24}\ \text{kg}$ and a radius of $r=6.38\times10^6\ \text{m}$ whereas for the sun at the end of its lifetime, $m=1.99\times10^{30}\ \text{kg}$ and $r=7500\ \text{km}=7.5\times10^6\ \text{m}$. The star possesses a radius of $r=10\ \text{km}$ $=1.0\times10^4\ \text{m}$ and a mass of $m=1.99\times10^{30}\ \text{kg}$.

Solve: **(a)** The earth has volume $V=\frac{4}{3}\pi r^3=\frac{4}{3}\pi(6.38\times10^6\ \text{m})^3=1.088\times10^{21}\ \text{m}^3$.

$$\text{density}=\frac{m}{V}=\frac{5.97\times10^{24}\ \text{kg}}{1.088\times10^{21}\ \text{m}^3}=(5.49\times10^3\ \text{kg/m}^3)\left(\frac{10^3\ \text{g}}{1\ \text{kg}}\right)\left(\frac{1\ \text{m}}{10^2\ \text{cm}}\right)^3=5.49\ \text{g/cm}^3$$

(b) $V=\frac{4}{3}\pi r^3=\frac{4}{3}\pi(7.5\times10^6\ \text{m})^3=1.77\times10^{21}\ \text{m}^3$

$$\text{density}=\frac{m}{V}=\frac{1.99\times10^{30}\ \text{kg}}{1.77\times10^{21}\ \text{m}^3}=(1.1\times10^9\ \text{kg/m}^3)\left(\frac{1\ \text{g/cm}^3}{1000\ \text{kg/m}^3}\right)=1.1\times10^6\ \text{g/cm}^3$$

(c) $V=\frac{4}{3}\pi r^3=\frac{4}{3}\pi(1.0\times10^4\ \text{m})^3=4.19\times10^{12}\ \text{m}^3$

$$\text{density}=\frac{m}{V}=\frac{1.99\times10^{30}\ \text{kg}}{4.19\times10^{12}\ \text{m}^3}=(4.7\times10^{17}\ \text{kg/m}^3)\left(\frac{1\ \text{g/cm}^3}{1000\ \text{kg/m}^3}\right)=4.7\times10^{14}\ \text{g/cm}^3$$

Reflect: For a fixed mass, the density scales as $1/r^3$. Thus, the answer to (c) can also be obtained from (b) as

$$(1.1\times10^6 \text{ g/cm}^3)\left(\frac{7.50\times10^6 \text{ m}}{1.0\times10^4 \text{ m}}\right)^3 = 4.7\times10^{14} \text{ g/cm}^3$$

1.17. Set Up: To calculate the densities, we need to find the spherical volume, $V = \frac{4}{3}\pi r^3$, and the mass of the atom or nucleus as the sum of the masses of its constituent particles. For the atom, $m = 2(m_p + m_n + m_e)$ while for the nucleus $m = 2(m_p + m_n)$. We thus need mass data from Appendix F: $m_p = 1.673\times10^{-27}$ kg; $m_n = 1.675\times10^{-27}$ kg; and $m_e = 9.109\times10^{-31}$ kg. The unit conversion factor $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$ is also needed.

Solve: (a) Given $r = 0.050 \text{ nm} = 0.050\times10^{-9}\text{m}$, $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.050\times10^{-9}\text{ m})^3 = 5.24\times10^{-31}\text{m}^3$.

$m = 2(m_p + m_n + m_e) = 6.70\times10^{-27}$ kg

$$\text{density} = \frac{m}{V} = \frac{6.70\times10^{-27}\text{ kg}}{5.24\times10^{-31}\text{ m}^3} = 1.3\times10^4 \text{ kg/m}^3 = 13 \text{ g/cm}^3$$

The density of the helium atom is 13 times larger than the density of pure water.

(b) Given $r = 1.0 \text{ fm} = 1.0\times10^{-15}$ m, $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(1.0\times10^{-15}\text{ m})^3 = 4.19\times10^{-45}\text{ m}^3$.

$$m = 2(m_p + m_n) = 6.70\times10^{-27}\text{ kg}$$

$$\text{density} = \frac{m}{V} = \frac{6.70\times10^{-27}\text{ kg}}{4.19\times10^{-45}\text{ m}^3} = 1.6\times10^{18}\text{ kg/m}^3 = 1.6\times10^{15}\text{ g/cm}^3$$

Reflect: In Problem 1.16 we found the density of a neutron star to be $4.7\times10^{14}\text{ g/cm}^3$. By comparison, the density of the helium nucleus is three times more than the density of a neutron star.

1.18. Set Up: Density is mass per unit volume, so we calculate the volume of the aluminum cube by using the formula $V = \ell^3$ where $\ell = 5.656$ cm is the length of a side of the cube. To express the answer in SI units, we convert grams to kilograms for the density. Note that we do not need to convert centimeters to meters because the lengths cancel in the formula for mass, leaving us only with units of mass.

Solve: Convert grams to kilograms for the density:

$$\rho = \left(2.7\text{ g/cm}^3\right)\left(\frac{1\text{ kg}}{1000\text{ g}}\right) = 2.7\times10^{-3}\text{ kg/cm}^3$$

Now use the definition of density and solve for the mass:

$$\rho = \frac{m}{V}$$

$$m = \rho V = \rho\ell^3$$

Insert the values for length and density to find the mass in SI units:

$$m = \rho\ell^3 = \left(2.7\times10^{-3}\text{ kg/cm}^3\right)\left(5.656\text{ cm}\right)^3$$
$$= 0.49\text{ kg}$$

where we have retained only two significant digits because the density is given to two significant digits.

Reflect: Notice how the units cm cancel in the expression for mass. Compare the result with the mass of the same size cube of water, which has a density of 1.00 g/cm^3. The mass of the water cube is $m_{\text{water}} = \left(1.00\text{ g/cm}^3\right)\left(5.656\text{ cm}\right)^3 = 181\text{ g}$. Because the aluminum cube is 2.7 times denser than water, if we multiply the mass of the water cube by 2.7 we should get the mass m of the aluminum cube. The result is $m = 2.7\times181\text{ g} = 490\text{ g}$, as expected.

1.19. Set Up: From Appendix A, a thin spherical shell has volume $V = At$, where $A = 4\pi r^2$ is the surface area of the shell and t is its thickness. We are given $r = 1.0\ \mu\text{m} = 1.0\times10^{-6}\ \text{m}$ and $t = 50.0\ \text{nm} = 50.0\times10^{-9}\ \text{m}$, and we know the unit conversions $1\ \text{m}^3 = 10^6\ \text{cm}^3$ and $1\ \text{mg} = 10^{-3}\ \text{g}$.

Solve: $V = 4\pi r^2 t = 4\pi(1.0\times10^{-6}\ \text{m})^2(50.0\times10^{-9}\ \text{m}) = 6.28\times10^{-19}\ \text{m}^3 = 6.28\times10^{-13}\ \text{cm}^3$

$$\text{mass} = (\text{density})(\text{volume}) = (1.0\ \text{g/cm}^3)(6.28\times10^{-13}\ \text{cm}^3) = 6.28\times10^{-13}\ \text{g} = 6.28\times10^{-10}\ \text{mg}$$

***1.20. Set Up:** The mass can be calculated as the product of the density and volume. The volume of the washer is the volume V_d of a solid disk of radius r_d minus the volume V_h of the disk-shaped hole of radius r_h. In general, the volume of a disk of radius *r* and thickness *t* is $\pi r^2 t$. We also need to apply the unit conversions $1\ \text{m}^3 = 10^6\ \text{cm}^3$ and $1\ \text{g/cm}^3 = 10^3\ \text{kg/m}^3$.

Solve: The volume of the washer is

$$V = V_\text{d} - V_\text{h} = \pi(r_\text{d}{}^2 - r_\text{h}{}^2)t = \pi[(2.25\ \text{cm})^2 - (0.625\ \text{cm})^2](0.150\ \text{cm}) = 2.20\ \text{cm}^3$$

The density of the washer material is $8600\ \text{kg/m}^3[(1\ \text{g/cm}^3)/(10^3\ \text{kg/m}^3)] = 8.60\ \text{g/cm}^3$. Finally, the mass of the washer is: $\text{mass} = (\text{density})(\text{volume}) = (8.60\ \text{g/cm}^3)(2.20\ \text{cm}^3) = 18.9\ \text{g}$.

Reflect: This mass corresponds to a weight of about 0.7 oz, a reasonable value for a washer.

1.21. Set Up: The world population at the time of writing is about 6.4×10^9 people. Estimate an average mass of a person to be about 50 kg, which corresponds to a weight of about 110 lbs.

Solve: The total mass of all the people is about $(50\ \text{kg/person})(6.4\times10^9\ \text{persons}) = 3\times10^{11}\ \text{kg}$

1.22. Set Up: We will divide the total thickness of the stack of paper by the number of sheets of paper, then convert the result to micrometers. Recall that 1 in. = 2.54 cm.

Solve: The thickness *t* of a single sheet of paper is

$$t = \frac{\text{total thickness}}{\text{number of sheets}} = \frac{2\ \text{in.}}{500} = 0.004\ \text{in.}$$

Converting this result to micrometers gives

$$t = (0.004\ \text{in})\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)\left(\frac{10^6\ \mu\text{m}}{1\ \text{m}}\right) = 1\times10^2\ \mu\text{m}$$

Reflect: Human hair ranges from 30 to 100 μm, so this result seems reasonable.

1.23. Set Up: Assume that the density of a cell is $1000\ \text{kg/m}^3$, the same as for water. Also assume a mass of 70 kg (a weight of about 150 lb) for a typical person. The volume of a sphere is $V = \frac{4}{3}\pi r^3$.

Solve: The volume is: $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(1.0\times10^{-6}\ \text{m})^3 = 4.2\times10^{-18}\ \text{m}^3$. The mass of a cell is

$$\text{mass} = (\text{density})(\text{volume}) = (1000\ \text{kg/m}^3)(4.2\times10^{-18}\ \text{m}^3) = 4\times10^{-15}\ \text{kg}$$

The number of cells in the typical person is then $(70\ \text{kg})/(4\times10^{-15}\ \text{kg/cell}) = 2\times10^{16}$ cells.

***1.24. Set Up:** Estimate that we blink 10 times per minute and a typical lifetime is 80 years. Convert this into blinks per lifetime using $1\ \text{year} = 365\ \text{days}$, $1\ \text{day} = 24\ \text{h}$, $1\ \text{h} = 60\ \text{min}$.

Solve: The number of blinks is $(10\ \text{per min})\left(\frac{60\ \text{min}}{1\ \text{h}}\right)\left(\frac{24\ \text{h}}{1\ \text{day}}\right)\left(\frac{365\ \text{days}}{1\ \text{year}}\right)(80\ \text{year/lifetime}) = 4\times10^8$.

Reflect: Our estimate of the number of blinks per minute can be off by a factor of 2 but our calculation is surely accurate to within a power of 10.

1.25. Set Up: Estimate the diameter of a drop to be $d = 2$ mm. The volume of a spherical drop is $V = \frac{4}{3}\pi r^3 = \frac{1}{6}\pi d^3$ and $10^3\ \text{cm}^3 = 1\ \text{L}$.

Solve: $V = \frac{1}{6}\pi(0.2\ \text{cm})^3 = 4\times10^{-3}\ \text{cm}^3$. The number of drops in 1.0 L is $\frac{1000\ \text{cm}^3}{4\times10^{-3}\ \text{cm}^3} = 2\times10^5$.

Reflect: Since $V \propto d^3$, if our estimate of the diameter of a drop is off by a factor of 2 then our estimate of the number of drops is off by a factor of 8.

1.26. Set Up: Estimate the thickness of a dollar bill by measuring a short stack, say 10, and dividing the measurement by the total number of bills. I obtain a thickness of roughly 1 mm. From Appendix F, the distance from the earth to the moon is 3.8×10^8 m. The number of bills is simply this distance divided by the thickness of one bill.

Solve: $N_{\text{bills}} = \left(\frac{3.8\times10^8\ \text{m}}{0.1\ \text{mm/bill}}\right)\left(\frac{10^3\ \text{mm}}{1\ \text{m}}\right) = 3.8\times10^{12}\ \text{bills} \approx 4\times10^{12}\ \text{bills}$

Reflect: This answer represents 4 trillion dollars! The cost of a single space shuttle mission in 2005 was significantly less—roughly 1 billion dollars.

1.27. Set Up: For part (a), estimate that a person takes 12 breaths per minute. In part (b), use the relation for the volume of a sphere, $V = \frac{4}{3}\pi r^3$, to calculate the radius required as $r = [3V/(4\pi)]^{1/3}$.

Solve: (a) The estimated number of breaths in 2 weeks equals

$$(12\ \text{breaths/min})\left(\frac{60\ \text{min}}{1\ \text{h}}\right)\left(\frac{24\ \text{h}}{1\ \text{day}}\right)\left(\frac{7\ \text{days}}{1\ \text{week}}\right)(2\ \text{weeks}) = 2.4\times10^5\ \text{breaths}$$

The total amount of air breathed by one person in two weeks is

$$V = \left(\frac{1}{2}\ \text{L/breath}\right)(2.4\times10^5\ \text{breaths})\left(\frac{10^{23}\ \text{m}^3}{1\ \text{L}}\right) = 1\times10^2\ \text{m}^3$$

(b) For a spherical vehicle, the radius required is

$$r = \left(\frac{3V}{4\pi}\right)^{1/3} = \left[\frac{3(1\times10^2\ \text{m}^3)}{4\pi}\right]^{1/3} = 3\ \text{m}$$

The diameter of the space station needs to be about 6 m to contain the air for one person for 2 weeks.

***1.28. Set Up:** An average middle-aged (40-year-old) adult at rest has a heart rate of roughly 75 beats per minute. To calculate the number of beats in a lifetime, use the current average lifespan of 80 years. The volume of blood pumped during this interval is then the volume per beat multiplied by the total beats.

Solve: $N_{\text{beats}} = (75\ \text{beats/min})\left(\frac{60\ \text{min}}{1\ \text{h}}\right)\left(\frac{24\ \text{h}}{1\ \text{day}}\right)\left(\frac{365\ \text{days}}{1\ \text{year}}\right)\left(\frac{80\ \text{years}}{\text{lifespan}}\right) = 3\times10^9\ \text{beats/lifespan}$

$$V_{\text{blood}} = (50\ \text{cm}^3/\text{beat})\left(\frac{1\ \text{L}}{1000\ \text{cm}^3}\right)\left(\frac{1\ \text{gal}}{3.788\ \text{L}}\right)\left(\frac{3\times10^9\ \text{beats}}{\text{lifespan}}\right) = 4\times10^7\ \text{gal/lifespan}$$

1.29. Set Up: Estimate that one step is $\frac{1}{3}$ m. Estimate that you walk 100 m in 1 minute. The distance to the moon is 3.8×10^8 m.

Solve: The time it takes is

$$t = \left(\frac{1\ \text{min}}{100\ \text{m}}\right)(3.8\times10^8\ \text{m}) = 3.8\times10^6\ \text{min}$$

which is about 7 years. The number of steps would be

$$\frac{3.8\times10^8\ \text{m}}{\frac{1}{3}\ \text{m/step}} = 1\times10^9\ \text{steps}$$

1.30. Set Up: Assume an average weight of 120 lbs. We need to convert this to ounces since we are given the price per ounce of gold. Next, use the formula for density ($\rho = m/V$) to find the volume of 120 lbs of gold, and convert that volume to cubic feet. The density of gold is 19.3 g/cm^3.

Solve: The price p of your weight in gold is

$$p = (\$1500/\text{oz})\left(\frac{1\text{ oz}}{0.0625\text{ lb}}\right)(120\text{ lb}) = \$2.88\times10^6$$

The volume of 120 lbs of gold can be calculated from its weight (which we convert to mass) and the formula for density:

$$\rho = \frac{m}{V}$$

$$V = \frac{m}{\rho} = \left(\frac{120\text{ lb}}{19.3\text{ g/cm}^3}\right)\left(\frac{1\text{ kg}}{2.2\text{ lb}}\right)\left(\frac{1000\text{ g}}{1\text{ kg}}\right)\left(\frac{1\text{ in.}}{2.54\text{ cm}}\right)^3\left(\frac{1\text{ ft}}{12\text{ in.}}\right)^3$$

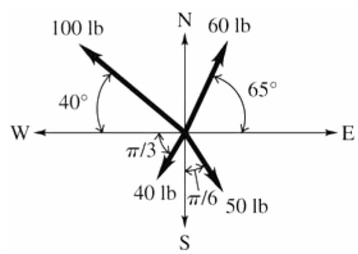
$$= 0.10\text{ ft}^3$$

Reflect: Since gold is almost 20 times denser than water, this volume seems reasonable for 120 lbs of gold.

1.31. Set Up: Convert the radian values to degrees as

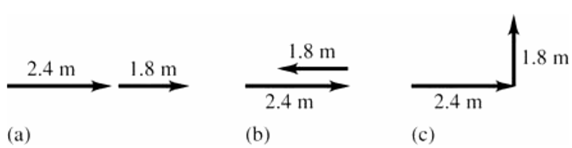
$$\frac{\pi}{3}\text{ rad} = 60°;\ \text{and}\ \frac{\pi}{6}\text{ rad} = 30°$$

Solve: The vectors are shown in the figure below.



***1.32. Set Up:** The sum with the largest magnitude is when the two displacements are parallel and the sum with the smallest magnitude is when the two displacements are antiparallel.

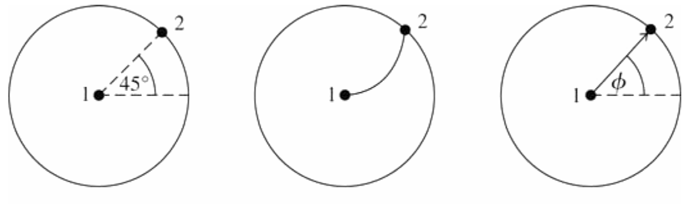
Solve: The orientations of the displacements that give the desired sum are shown in the figure below.



Reflect: The orientations of the two displacements can be chosen such that the sum has any value between 0.6 m and 4.2 m.

1.33. Set Up: The displacement vector is directed from the initial position of the object to the final position.

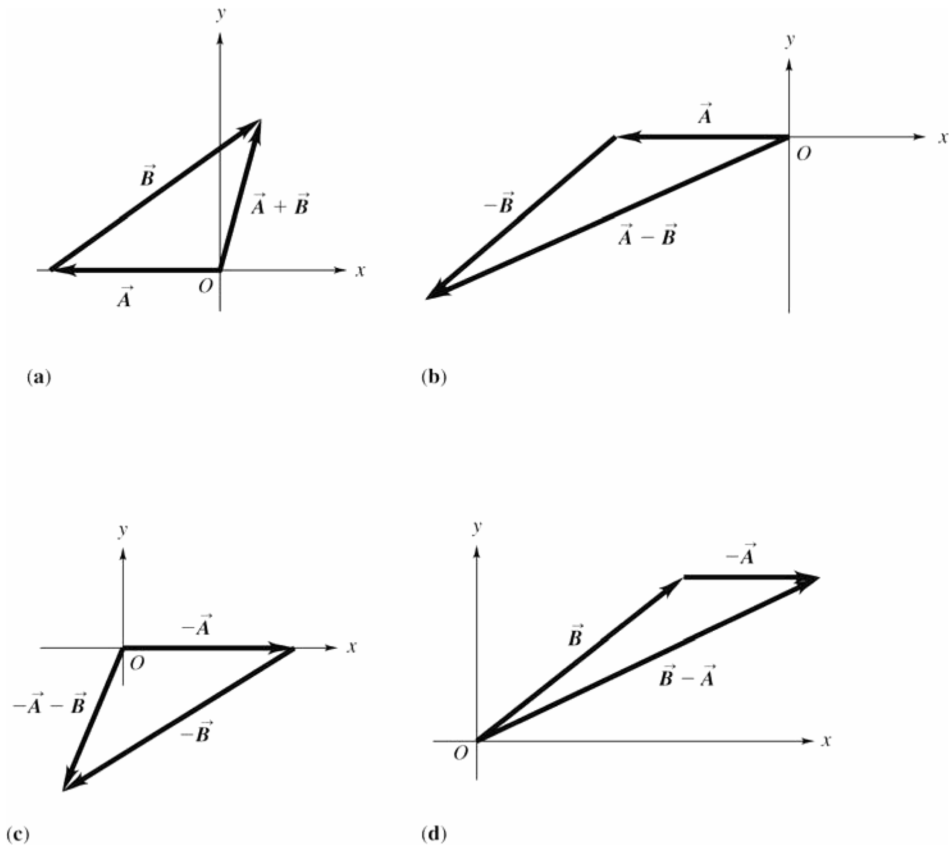
Solve: (a) The initial and final positions of the bug are shown in Figure (a) below. The curved path of the bug is shown in Figure (b) and the bug's displacement vector is shown in Figure (c).



(a) (b) (c)

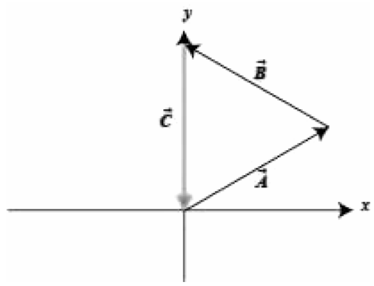
(b) The magnitude of the displacement vector is the length of the line that connects points 1 and 2 and is equal to the radius of the turntable, 6 in. The direction of the displacement vector is shown in Figure (c) above, with $\phi = 45°$.

1.34. Set Up: Draw the vectors to scale on graph paper, using the tip to tail addition method. For part (a), simply draw $\vec{B}$ so that its tail lies at the tip of $\vec{A}$. Then draw the vector $\vec{R}$ from the tail of $\vec{A}$ to the tip of $\vec{B}$. For (b), add $-\vec{B}$ to $\vec{A}$ by drawing $-\vec{B}$ in the opposite direction to $\vec{B}$. For (c), add $-\vec{A}$ to $-\vec{B}$. For (d), add $-\vec{A}$ to $\vec{B}$.
Solve: The vector sums and differences are shown in the figures below.



Reflect: $-\vec{A} - \vec{B} = -(\vec{A} + \vec{B})$ so it has the same magnitude and opposite direction as $\vec{A} + \vec{B}$. Similarly, $\vec{B} - \vec{A} = -(\vec{A} - \vec{B})$ and $\vec{B} - \vec{A}$ and $\vec{A} - \vec{B}$ have equal magnitudes and opposite directions.

1.35. Set Up: Draw the vectors to scale on graph paper, using the tip to tail addition method. The vector $\vec{C}$ should go from the tip of $\vec{A} + \vec{B}$ to the origin.
Solve: The vector $\vec{C}$ is shown in the figure below.



***1.36.** **Set Up:** Use components to add the two forces. Take the $+x$ direction to be forward and the $+y$ direction to be upward.

Solve: The second force has components $F_{2x} = F_2 \cos 32.4° = 433$ N and $F_{2y} = F_2 \sin 32.4° = 275$ N. The first force has components $F_{1x} = 725$ N and $F_{1y} = 0$.

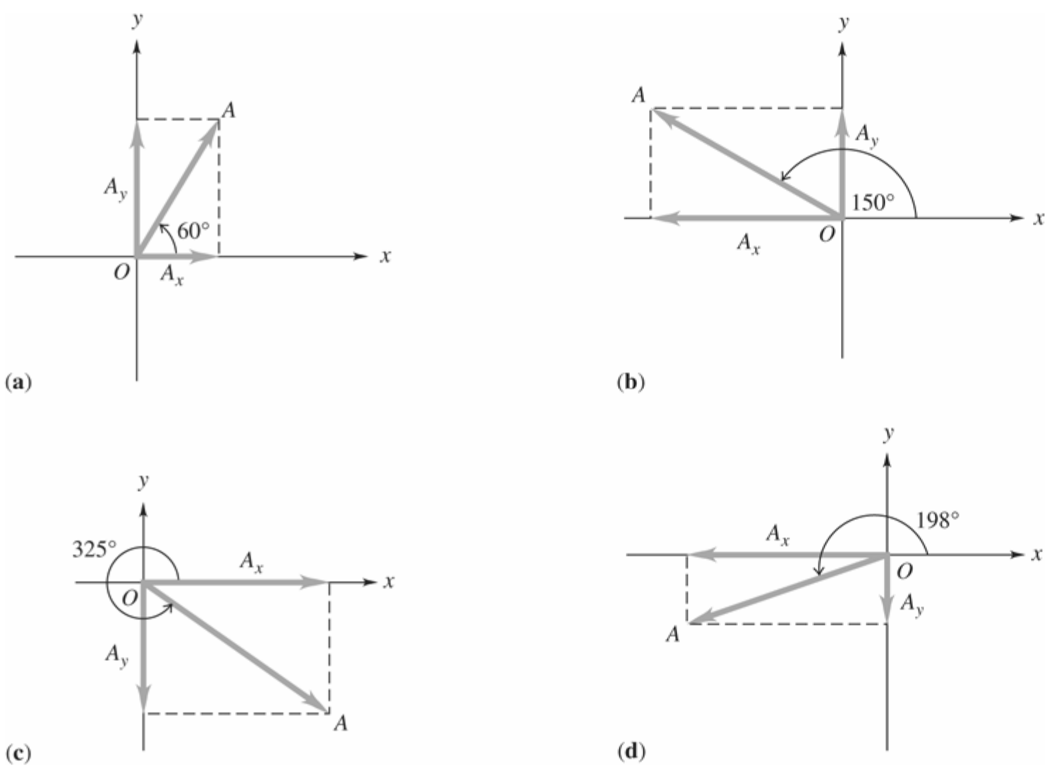
$$F_x = F_{1x} + F_{2x} = 1158 \text{ N} \text{ and } F_y = F_{1y} + F_{2y} = 275 \text{ N}$$

The resultant force is 1190 N in the direction 13.4° above the forward direction.

Reflect: Since the two forces are not in the same direction the magnitude of their vector sum is less than the sum of their magnitudes.

1.37. **Set Up:** In each case the direction of the vector is specified by the angle θ measured counterclockwise from the $+x$ axis. The components are calculated as: $A_x = A \cos \theta$; $A_y = A \sin \theta$.

Solve: **(a)** $A_x = (50.0 \text{ N})(\cos 60°) = +25.0$ N; $A_y = (50.0 \text{ N})(\sin 60°) = +43.3$ N. The sketch of the vector and its components in Figure (a) below shows that both components are positive and that $|A_y| > |A_x|$.

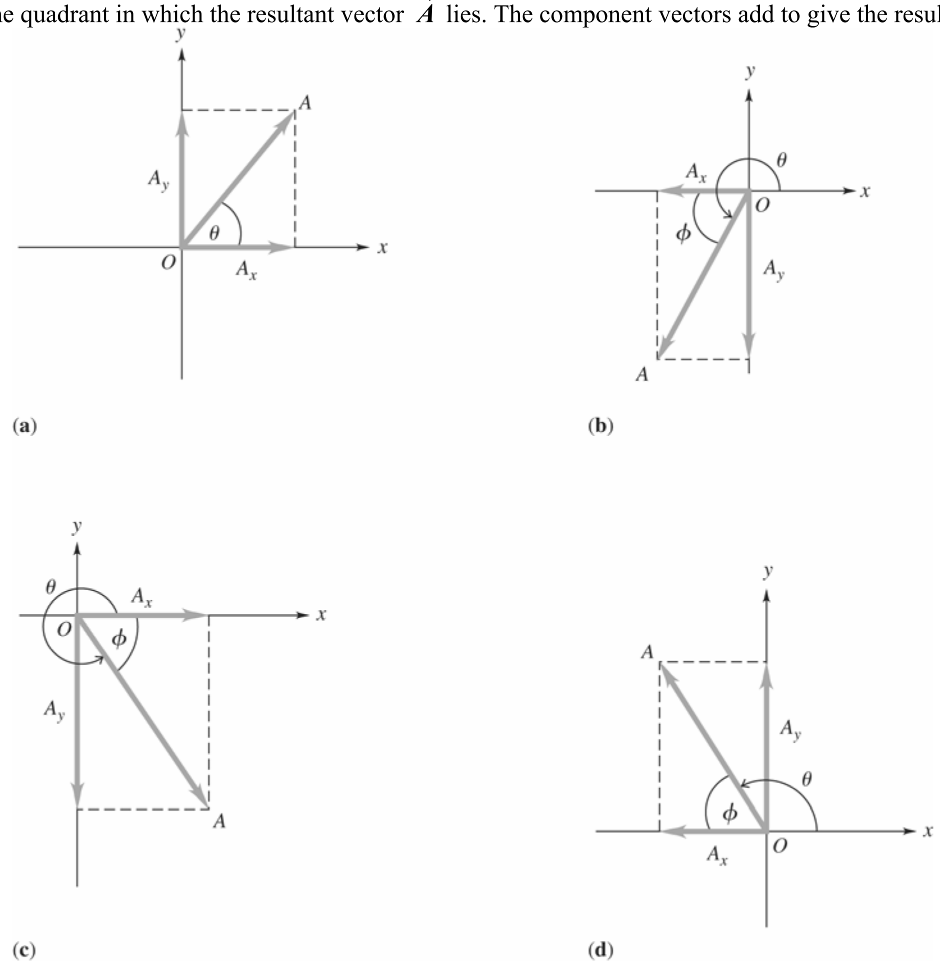


(b) $\theta = (5\pi/6 \text{ rad})(180°/\pi \text{ rad}) = 150°$; $A_x = (75 \text{ m/s})(\cos 150°) = -65.0 \text{ m/s}$; $A_y = (75 \text{ m/s})(\sin 150°) = +37.5 \text{ m/s}$. Figure (b) above shows that A_x is negative, A_y is positive, and $|A_x| > |A_y|$.

(c) $A_x = (254 \text{ lb})(\cos 325°) = 208 \text{ lb}$; $A_y = (254 \text{ lb})(\sin 325°) = -146 \text{ lb}$. Figure (c) above shows that A_x is positive, A_y is negative, and $|A_x| > |A_y|$.

(d) $\theta = (1.1\pi \text{ rad})(180°/\pi \text{ rad}) = 198°$; $A_x = (69 \text{ km})(\cos 198°) = -66 \text{ km}$; $A_y = (69 \text{ km})(\sin 198°) = -21 \text{ km}$. Figure (d) above shows that both A_x and A_y are negative and $|A_x| > |A_y|$.

***1.38. Set Up:** In each case, create a sketch (see the figure below) showing the components and the resultant to determine the quadrant in which the resultant vector $\vec{A}$ lies. The component vectors add to give the resultant.



Solve: **(a)** $A = \sqrt{A_x^{\,2} + A_y^{\,2}} = \sqrt{(4.0 \text{ m})^2 + (5.0 \text{ m})^2} = 6.4 \text{ m}$; $\tan\theta = \dfrac{A_y}{A_x} = \dfrac{5.0 \text{ m}}{4.0 \text{ m}}$ and $\theta = 51°$.

(b) $A = \sqrt{(-3.0 \text{ km})^2 + (-6.0 \text{ km})^2} = 6.7 \text{ km}$; $\tan\theta = \dfrac{-6.0 \text{ m}}{-3.0 \text{ m}}$ and $\theta = 243°$.

(My calculator gives $\phi = 63°$ and $\theta = \phi + 180°$.)

(c) $A = \sqrt{(9.0 \text{ m/s})^2 + (-17 \text{ m/s})^2} = 19 \text{ m/s}$; $\tan\theta = \dfrac{-17 \text{ m/s}}{9 \text{ m/s}}$ and $\theta = 298°$.

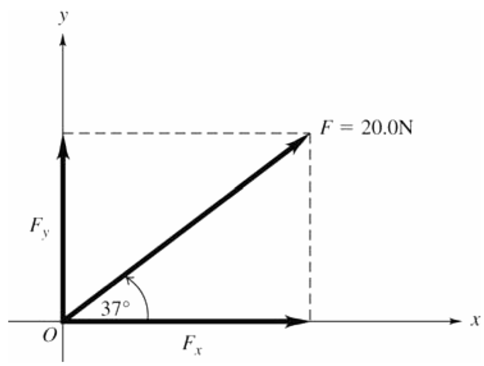
(My calculator gives $\phi = -62°$ and $\theta = \phi + 360°$.)

(d) $A = \sqrt{(-8.0\text{ N})^2 + (12\text{ N})^2} = 14\text{ N}$. $\tan\theta = \dfrac{12\text{ N}}{-8.0\text{ N}}$ and $\theta = 124°$.

(My calculator gives $\phi = -56°$ and $\theta = \phi + 180°$.)

Reflect: The signs of the components determine the quadrant in which the resultant lies.

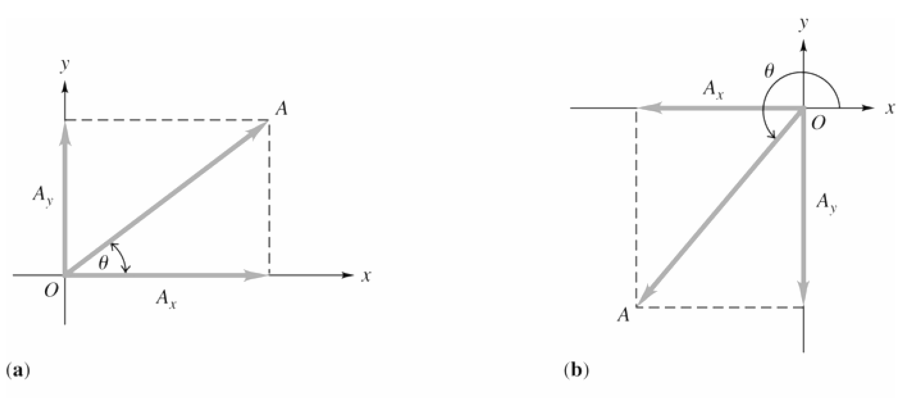
1.39. Set Up: Use coordinates for which the $+x$ axis is horizontal and the $+y$ direction is upward. The force $\vec{F}$ and its x and y components are shown in the figure below.

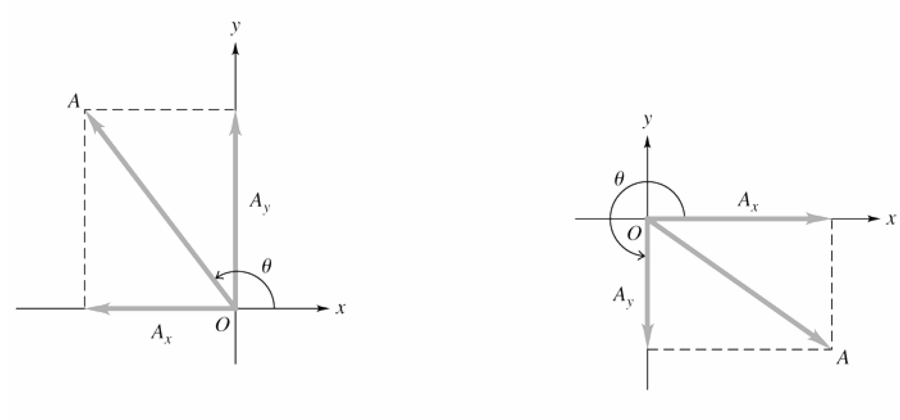


Solve: **(a)** $F_x = F(\cos 37°) = (20.0\text{ N})(\cos 37°) = 16.0\text{ N}$

(b) $F_y = F \sin 37° = (20.0\text{ N})(\sin 37°) = 12.0\text{ N}$

***1.40. Set Up:** In each case, use a sketch (see the figure below) showing the components and the resultant in order to determine the quadrant in which the resultant vector $\vec{A}$ lies. The component vectors add to give the resultant.





(c) (d)

Solve: (a) $A = \sqrt{A_x^2 + A_y^2} = \sqrt{(8.0 \text{ lb})^2 + (6.0 \text{ lb})^2} = 10.0 \text{ lb}$; $\tan\theta = \dfrac{A_y}{A_x} = \dfrac{6.0 \text{ lb}}{8.0 \text{ lb}}$ and $\theta = 37°$

(b) $A = \sqrt{(-24 \text{ m/s})^2 + (-31 \text{ m/s})^2} = 39 \text{ m/s}$; $\tan\theta = \dfrac{-31 \text{ m/s}}{-24 \text{ m/s}}$ and $\theta = 232°$

(My calculator gives $\phi = 52°$ and $\theta = \phi + 180°$.)

(c) $A = \sqrt{(-1500 \text{ km})^2 + (2000 \text{ km})^2} = 2500 \text{ km}$; $\tan\theta = \dfrac{2000 \text{ km}}{-1500 \text{ km}}$ and $\theta = 127°$

(My calculator gives $\phi = -53°$ and $\theta = \phi + 180°$.)

(d) $A = \sqrt{(71.3 \text{ N})^2 + (-54.7 \text{ N})^2} = 89.9 \text{ N}$; $\tan\theta = \dfrac{-54.7 \text{ N}}{71.3 \text{ N}}$ and $\theta = 323°$

(My calculator gives $\phi = -37°$ and $\theta = \phi + 360°$.)

1.41. Set Up: For each vector, use the relations $R_x = R\cos\theta$ and $R_y = R\sin\theta$.

Solve: For vector $\vec{A}$: $A_x = (12.0 \text{ m})\cos(90° - 37°) = 7.2 \text{ m}$; $A_y = (12.0 \text{ m})\sin(90° - 37°) = 9.6 \text{ m}$.

For vector $\vec{B}$: $B_x = (15.0 \text{ m})\cos(320°) = 11.5 \text{ m}$; $B_y = (15.0 \text{ m})\sin(320°) = -9.6 \text{ m}$. For vector $\vec{C}$: $C_x = (6.0 \text{ m})\cos(240°) = -3.0 \text{ m}$; $C_y = (6.0 \text{ m})\sin(240°) = -5.2 \text{ m}$.

1.42. Set Up: For parts (a) and (c), apply the appropriate signs to the relations $R_x = A_x + B_x$ and $R_y = A_y + B_y$. For (b) and (d), find the magnitude as $R = \sqrt{R_x^2 + R_y^2}$ and the direction as $\theta = \tan^{-1}(R_y/R_x)$.

Solve: (a) $R_x = A_x + B_x = 1.30 \text{ cm} + 4.10 \text{ cm} = 5.40 \text{ cm}$; $R_y = A_y + B_y = 2.25 \text{ cm} + (-3.75 \text{ cm}) = -1.50 \text{ cm}$

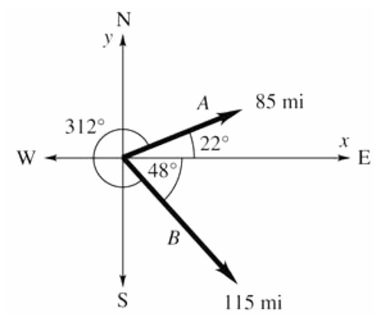
(b) $R = \sqrt{R_x^2 + R_y^2} = \sqrt{(5.40 \text{ cm})^2 + (-1.50 \text{ cm})^2} = 5.60 \text{ cm}$; $\theta = \tan^{-1}[(-1.50 \text{ cm})/(5.40 \text{ cm})] - 15.5°$. The resultant vector thus makes an angle of $344.5°$ counterclockwise from the +*x* axis.

(c) $R_x = B_x + (-A_x) = 4.10 \text{ cm} + (-1.30 \text{ cm}) = 2.80 \text{ cm}$; $R_y = B_y + (-A_y) = -3.75 \text{ cm} + (-2.25 \text{ cm}) = -6.00 \text{ cm}$

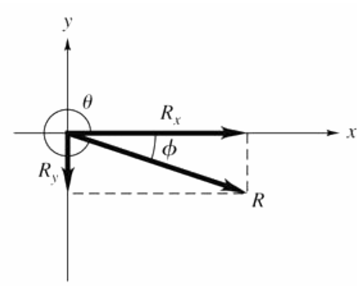
(d) $R = \sqrt{(2.80 \text{ cm})^2 + (-6.00 \text{ cm})^2} = 6.62 \text{ cm}$; $\theta = \tan^{-1}[(-6.00 \text{ cm})/(2.80 \text{ cm})] = -65.0°$. The resultant vector thus makes an angle of $295.0°$ counterclockwise from the +*x* axis.

Reflect: Note that $\vec{B} - \vec{A}$ has a larger magnitude than $\vec{B} + \vec{A}$. Vector addition is very different from addition of scalars.

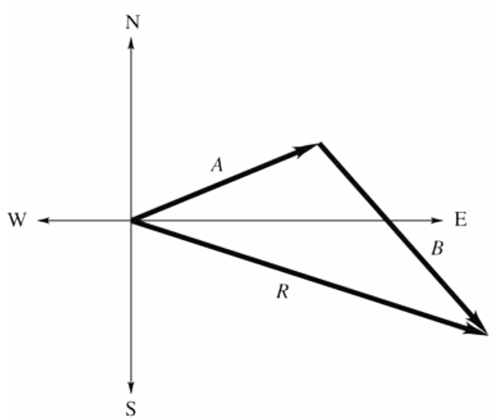
1.43. Set Up: Use coordinates where $+x$ is east and $+y$ is north. $\vec{A}$ and $\vec{B}$ are the two given displacements (see Figure (a) below). Displacement $\vec{B}$ makes an angle of $\theta = 312°$ counterclockwise from the $+x$ axis. Calculate $\vec{R} = \vec{A} + \vec{B}$.



(a)



(b)



(c)

Solve: (a) $A_x = A\cos 22° = (85\text{ mi})(\cos 22°) = 78.8\text{ mi}$

$A_y = A\sin 22° = (85\text{ mi})(\sin 22°) = 31.8\text{ mi}$

$B_x = B\cos 312° = (115\text{ mi})(\cos 312°) = 77.0\text{ mi}$

$B_y = B\sin 312° = (115\text{ mi})(\sin 312°) = -85.5\text{ mi}$

$R_x = A_x + B_x = 78.8\text{ mi} + 77.0\text{ mi} = 155.8\text{ mi}$

$R_y = A_y + B_y = 31.8\text{ mi} + (-85.5\text{ mi}) = -53.7\text{ mi}$

$R = \sqrt{R_x{}^2 + R_y{}^2} = \sqrt{(155.8\text{ mi})^2 + (-53.7\text{ mi})^2} = 165\text{ mi}$; $\tan\theta = \dfrac{-53.7\text{ mi}}{155.8\text{ mi}}$ and $\theta = 341°$

or $\phi = 19°$ south of east, as shown in Figure (b) above.

(b) The vector addition diagram for $\vec{R} = \vec{A} + \vec{B}$ is given in Figure (c) above. The magnitude and direction of $\vec{R}$ in this diagram agrees with our calculation using components.

1.44. Set Up: Break vectors $\vec{A}$ and $\vec{B}$ into their components and do the addition, then reconvert them into magnitude and angle. Note that all angles should be measured counterclockwise from the positive *x* axis, so we will convert the angle of 60° counterclockwise from the *y* axis to 150° from the *x* axis.

Solve: (a) The components of vectors $\vec{A}$ and $\vec{B}$ are

$$A_x = A\cos\theta_A = (20\text{ m})(\cos 30°) = 17.3\text{ m}$$
$$A_y = A\sin\theta_A = (20\text{ m})(\sin 30°) = 10.0\text{ m}$$
$$B_x = B\cos\theta_B = (15\text{ m})(\cos 150°) = -13.0\text{ m}$$
$$B_y = B\sin\theta_B = (15\text{ m})(\sin 150°) = 7.50\text{ m}$$

Calculating the components of $\vec{R} = \vec{A} - \vec{B}$ gives

$$R_x = A_x - B_x = 17.3\text{ m} - (-13.0\text{ m}) = 30.3\text{ m}$$
$$R_y = A_y - B_y = 10.0\text{ m} - 7.50\text{ m} = 2.5\text{ m}$$

The magnitude of $\vec{R}$ is

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(30.3\text{ m})^2 + (2.5\text{ m})^2} = 30.4\text{ m}$$

The vector $\vec{R}$ is in the first quadrant, so its angle counterclockwise from the positive *x* axis is

$$\theta = \text{atan}\left(\frac{R_y}{R_x}\right) = \text{atan}\left(\frac{2.5\text{ m}}{30.3\text{ m}}\right) = 4.72°$$

(b) Calculating the components of $\vec{R} = 2\vec{A} + \vec{B}$ gives

$$R_x = 2A_x + B_x = 2(17.3\text{ m}) + (-13.0\text{ m}) = 21.7\text{ m}$$
$$R_y = 2A_y + B_y = 2(10.0\text{ m}) + 7.50\text{ m} = 27.5\text{ m}$$

The magnitude of $\vec{R}$ is

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(21.7\text{ m})^2 + (27.5\text{ m})^2} = 35.0\text{ m}$$

The vector $\vec{R}$ is in the first quadrant, so its angle counterclockwise from the positive *x* axis is

$$\theta = \text{atan}\left(\frac{R_y}{R_x}\right) = \text{atan}\left(\frac{27.5\text{ m}}{21.7\text{ m}}\right) = 51.8°$$

(c) Calculating the components of $\vec{R} = -\vec{A} + 3\vec{B}$ gives

$$R_x = 2A_x + B_x = -17.3\text{ m} + 3(-13.0\text{ m}) = -56.3\text{ m}$$
$$R_y = 2A_y + B_y = -10.0\text{ m} + 3(7.50\text{ m}) = 12.5\text{ m}$$

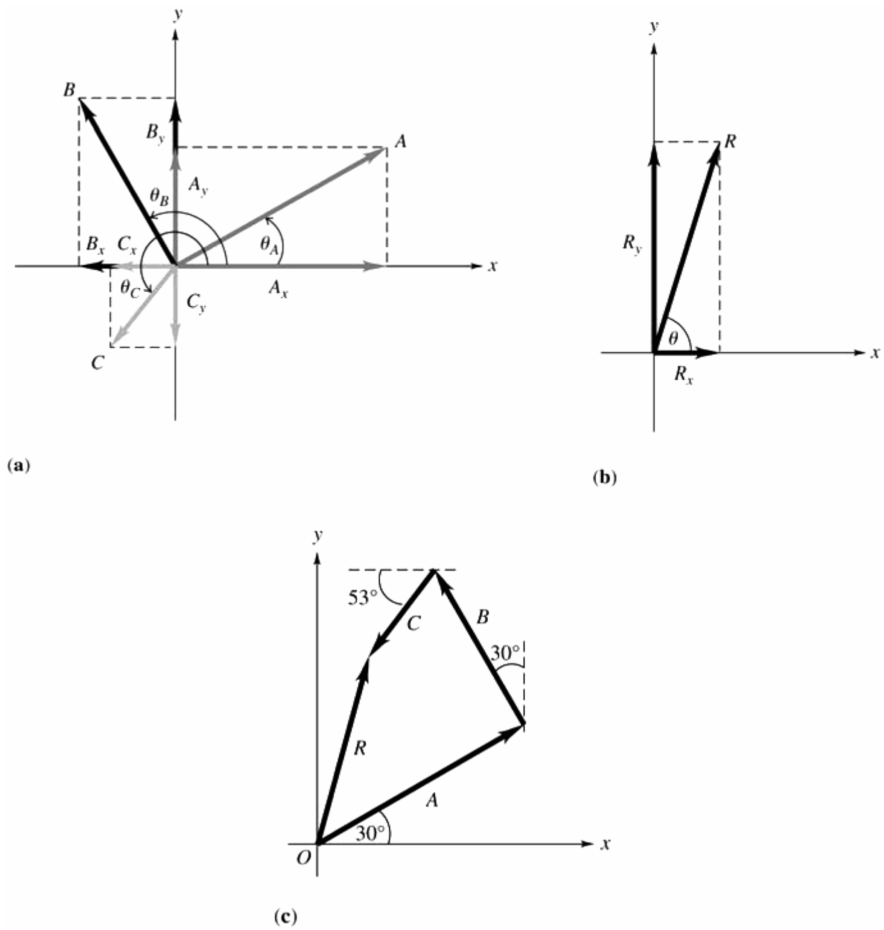
The magnitude of $\vec{R}$ is

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(-56.3\text{ m})^2 + (12.5\text{ m})^2} = 57.7\text{ m}$$

The vector $\vec{R}$ is in the second quadrant, so its angle counterclockwise from the positive *x* axis is

$$\theta = 180° - \left|\text{atan}\left(\frac{R_y}{R_x}\right)\right| = 180° - \left|\text{atan}\left(\frac{12.5\text{ m}}{-56.3\text{ m}}\right)\right| = 167°$$

1.45. Set Up: The counterclockwise angles each vector makes with the +*x* axis are: $\theta_A = 30°$, $\theta_B = 120°$, and $\theta_C = 233°$. The components of each vector are shown in Figure (a) below.



Solve: **(a)** $A_x = A \cos 30° = 87 \text{ N}$; $A_y = A \sin 30° = 50 \text{ N}$; $B_x = B \cos 120° = -40 \text{ N}$; $B_y = B \sin 120° = 69 \text{ N}$; $C_x = C \cos 233° = -24 \text{ N}$; $C_y = C \sin 233° = -32 \text{ N}$.

(b) $\vec{R} = \vec{A} + \vec{B} + \vec{C}$ is the resultant pull.

$$R_x = A_x + B_x + C_x = 87 \text{ N} + (-40 \text{ N}) + (-24 \text{ N}) = +23 \text{ N}$$
$$R_y = A_y + B_y + C_y = 50 \text{ N} + 69 \text{ N} + (-32 \text{ N}) = +87 \text{ N}$$

(c) R_x, R_y, and $\vec{R}$ are shown in Figure (b) above.

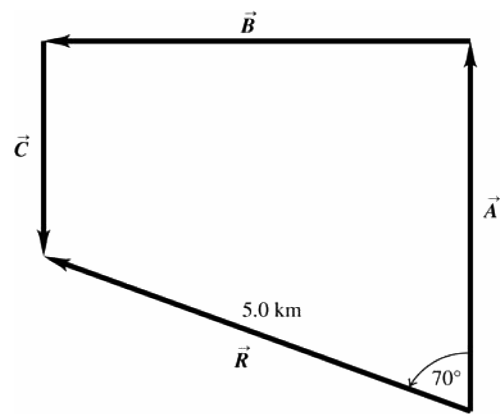
$$R = \sqrt{R_x^2 + R_y^2} = 90 \text{ N} \text{ and } \tan\theta = \frac{87 \text{ N}}{23 \text{ N}} \text{ so } \theta = 75°$$

(d) The vector addition diagram is given in Figure (c) above. Careful measurement gives an $\vec{R}$ value that agrees with our results using components.

***1.46. Set Up:** Use coordinates for which $+x$ is east and $+y$ is north. Each of the professor's displacement vectors makes an angle of 0° or 180° with one of these axes. The components of his total displacement can thus be calculated directly from $R_x = A_x + B_x + C_x$ and $R_y = A_y + B_y + C_y$.

Solve: (a) $R_x = A_x + B_x + C_x = 0 + (-4.75 \text{ km}) + 0 = -4.75 \text{ km} = 4.75 \text{ km west}$; $R_y = A_y + B_y + C_y = 3.25 \text{ km} + 0 + (-1.50 \text{ km}) = 1.75 \text{ km} = 1.75 \text{ km north}$; $R = \sqrt{R_x^2 + R_y^2} = 5.06 \text{ km}$; $\theta = \tan^{-1}(R_y/R_x) = \tan^{-1}[(+1.75)/(-4.75)] = -20.2°$; $\phi = 180° - 20.2° = 69.8°$ west of north

(b) From the scaled sketch in the figure below, the graphical sum agrees with the calculated values.



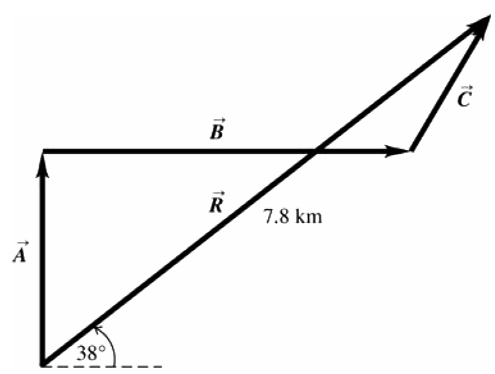
Reflect: The magnitude of his resultant displacement is very different from the distance he traveled, which is 159.50 km.

1.47. Set Up: Use coordinates for which $+x$ is east and $+y$ is north. The driver's vector displacements are $\vec{A} = 2.6$ km, 0° of north; $\vec{B} = 4.0$ km, 0° of east; $\vec{C} = 3.1$ km, 45° north of east.

Solve: $R_x = A_x + B_x + C_x = 0 + 4.0 \text{ km} + (3.1 \text{ km}) \cos(45°) = 6.2 \text{ km}$;

$R_y = A_y + B_y + C_y = 2.6 \text{ km} + 0 + (3.1 \text{ km})(\sin 45°) = 4.8 \text{ km}$; $R = \sqrt{R_x^2 + R_y^2} = 7.8 \text{ km}$;

$\theta = \tan^{-1}[(4.8 \text{ km})/(6.2 \text{ km})] = 38°$; $\vec{R} = 7.8$ km, 38° north of east. This result is confirmed by the figure below.



1.48. Set Up: We know that an object of mass 1000 g weighs 2.205 lbs and 16 oz = 1 lb.

Solve: $(5.00 \text{ oz})\left(\frac{1 \text{ lb}}{16 \text{ oz}}\right)\left(\frac{1000 \text{ g}}{2.205 \text{ lb}}\right) = 142 \text{ g}$ and $(5.25 \text{ oz})\left(\frac{1 \text{ lb}}{16 \text{ oz}}\right)\left(\frac{1000 \text{ g}}{2.205 \text{ lb}}\right) = 149 \text{ g}$

The acceptable limits are 142 g to 149 g.

Reflect: The range in acceptable weight is $\frac{1}{4}$ oz. Since $\frac{1}{4} \text{ oz} = 7 \text{ g}$, the range in mass of 7 g is consistent. As we will see in Chapter 4, mass has units of kilogram or gram and is a different physical quantity than weight, which can have units of ounces. But for objects close to the surface of the earth, mass and weight are proportional; we can therefore say that a certain weight is equivalent to a certain mass.

1.49. Set Up: The vector $\vec{B}$ will only have an x component, because it points along the negative x axis. The magnitude of this component is the magnitude of the vector $\vec{A}$.

Solve: (a) The magnitude of $\vec{A}$ is

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(3\text{ m/s})^2 + (4\text{ m/s})^2} = 5\text{ m/s}$$

so, in component form, $B_x = -5\text{ m/s}$ and $B_y = 0$.

(b) The components of $\vec{R} = \vec{A} - \vec{B}$ are

$$R_x = A_x - B_x = 3\text{ m/s} - (-5\text{ m/s}) = 8\text{ m/s}$$
$$R_y = A_y - B_y = 4\text{ m/s} - 0\text{ m/s} = 4\text{ m/s}$$

***1.50. Set Up:** The volume V of blood pumped during each heartbeat is the total volume of blood in the body divided by the number of heartbeats in 1.0 min. We will need to apply $1\text{ L} = 1000\text{ cm}^3$.

Solve: The number of heartbeats in 1.0 min is 75. The volume of blood is thus

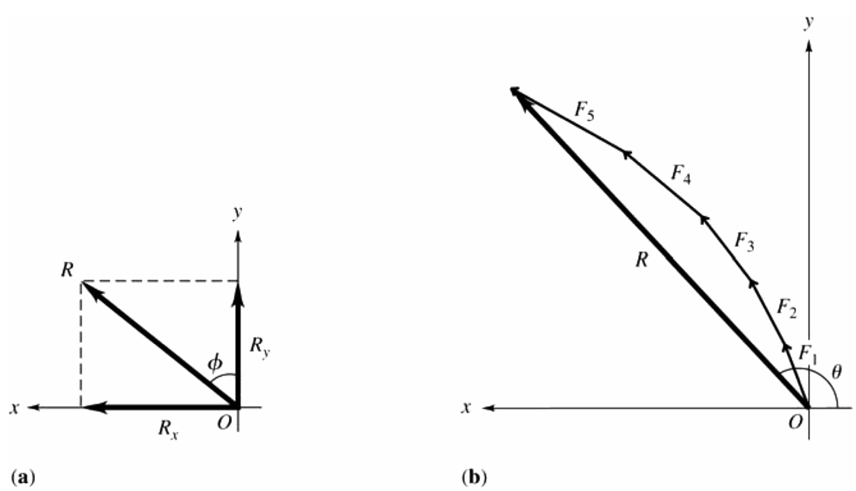
$$V = \frac{5.0\text{ L}}{75\text{ heartbeats}} = 6.7\times10^{-2}\text{ L} = 67\text{ cm}^3.$$

1.51. Set Up: The x axis is shown to lie along the axis of the bone. Let $F = 2.75\text{ N}$ be the magnitude of the force applied by each tendon. The angles that the tendons make with the x axis are $20.0°$, $30.0°$, $40.0°$, $50.0°$, and $60.0°$.

Solve: (a) $R_x = F_{1x} + F_{2x} + F_{3x} + F_{4x} + F_{5x}$

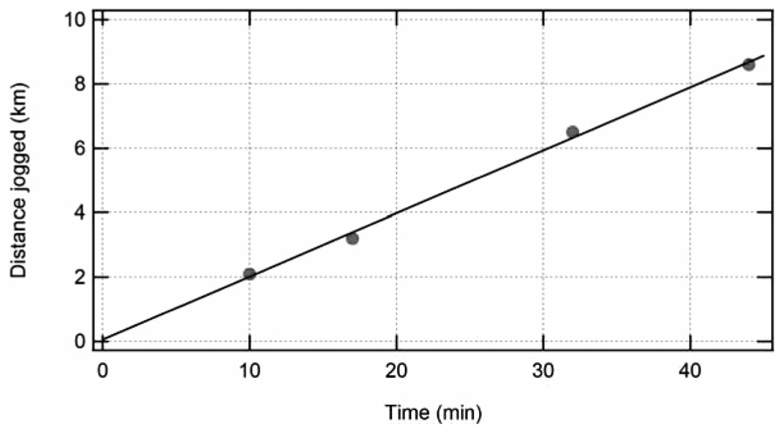
$$R_x = (2.75\text{ N})(\cos 20.0° + \cos 30.0° + \cos 40.0° + \cos 50.0° + \cos 60.0°) = 10.2\text{ N}$$
$$R_y = F_{1y} + F_{2y} + F_{3y} + F_{4y} + F_{5y}$$
$$R_y = (2.75\text{ N})(\sin 20.0° + \sin 30.0° + \sin 40.0° + \sin 50.0° + \sin 60.0°) = 8.57\text{ N}$$
$$R = \sqrt{R_x{}^2 + R_y{}^2} = 13.3\text{ N};\quad \tan\phi = \frac{8.57\text{ N}}{10.2\text{ N}}\quad\text{so}\quad \phi = 40.0°$$

The resultant $\vec{R}$ and its components are shown in Figure (a) below.



(b) The vector addition diagram is shown in Figure (b) above. Careful measurements in the diagram give results that agree with what we calculated by using components.

1.52. Set Up: The plot of distance versus time is shown below, and the best-fit line is drawn through the data. The jogger's speed is the slope of this line. Note the units for the plot; we will need to convert to m and s for the calculation.



Solve: **(a)** By using the grid in the plot, we can estimate the slope of the best-fit line to be $\frac{2\text{ km}}{10\text{ min}}$. Converting this to m/s gives her speed υ:

$$\upsilon = \frac{2\text{ km}}{10\text{ min}}\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right) = 3.3\text{ m/s}$$

(b) If she can job 2 km in 10 min, she should be able to jog 12 km in 60 min.

Reflect: The speed seems reasonable, as does the distance she jogs in 1 h.

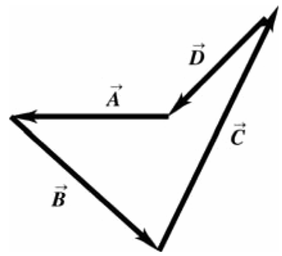
***1.53. Set Up:** Use coordinates for which $+x$ is east and $+y$ is north. The spelunker's vector displacements are $\vec{A} = 180$ m, 0° of west; $\vec{B} = 210$ m, 45° east of south; $\vec{C} = 280$ m, 30° east of north; and the unknown displacement $\vec{D}$ The vector sum of these four displacements is zero.

Solve: $A_x + B_x + C_x + D_x = -180\text{ m} + (210\text{ m})(\sin 45°) + (280\text{ m})(\sin 30°) + D_x = 0$ and $D_x = -108$ m

$A_y + B_y + C_y + D_y = (-210\text{ m})(\cos 45°) + (280\text{ m})(\cos 30°) + D_y = 0$ and $D_y = -94$ m

$$D = \sqrt{D_x{}^2 + D_y{}^2} = 143\text{ m};\ \theta = \tan^{-1}[(-94\text{ m})/(-108)] = 41°;\ \vec{\boldsymbol{D}} = 143\text{ m},\ 41°\text{ south of west}$$

This result is confirmed by the figure below.



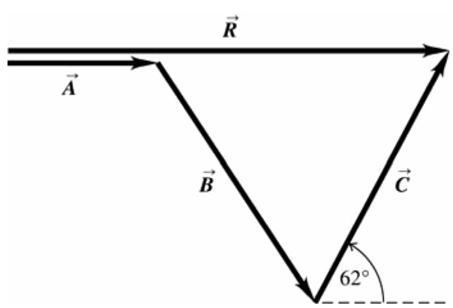
Reflect: We always add vectors by separately adding their *x* and *y* components.

1.54. Set Up: Use coordinates for which $+x$ is east and $+y$ is north. The vector displacements are $\vec{\boldsymbol{A}} = 2.00$ km, 0° of east; $\vec{\boldsymbol{B}} = 3.50$ m, 45° south of east; and $\vec{\boldsymbol{R}} = 5.80$ m, 0° east.

Solve: $C_x = R_x - A_x - B_x = 5.80\text{ km} - (2.00\text{ km}) - (3.50\text{ km})(\cos 45°) = 1.33\text{ km}$; $C_y = R_y - A_y - B_y$ $= 0\text{ km} - 0\text{ km} - (-3.50\text{ km})(\sin 45°) = 2.47\text{ km}$;

$$C = \sqrt{(1.33\text{ km})^2 + (2.47\text{ km})^2} = 2.81\text{ km};\ \theta = \tan^{-1}[(2.47\text{ km})/(1.33\text{ km})] = 61.7°\ \text{north of east}$$

The vector addition diagram in the figure below shows good qualitative agreement with these values.



1.55. Set Up: Use coordinates having a horizontal $+x$ axis and an upward $+y$ axis. Then $R_x = 5.60$ N.

Solve: $A_x + B_x = R_x$ and $A\cos 32° + B\sin 32° = R_x$. Since $A = B$, $2A\cos 32° = R_x$ and $A = R_x/[(2)(\cos 32°)]$ $= 3.30$ N.

1.56. Set Up: The four displacements return her to her starting point, so $\vec{\boldsymbol{D}} = -(\vec{\boldsymbol{A}} + \vec{\boldsymbol{B}} + \vec{\boldsymbol{C}})$, where $\vec{\boldsymbol{A}}$, $\vec{\boldsymbol{B}}$, and $\vec{\boldsymbol{C}}$ are in the three given displacements and $\vec{\boldsymbol{D}}$ is the displacement for her return. Let $+x$ be east and $+y$ be north.

Solve: **(a)** $D_x = -[(147\text{ km})\sin 85° + (106\text{ km})\sin 167° + (166\text{ km})\sin 235°] = -34.3\text{ km}$

$D_y = -[(147\text{ km})\cos 85° + (106\text{ km})\cos 167° + (166\text{ km})\cos 235°] = +185.7\text{ km}$

$D = \sqrt{(-34.3\text{ km})^2 + (185.7\text{ km})^2} = 189\text{ km}$

(b) The direction relative to north is $\phi = \arctan\left(\dfrac{34.3\text{ km}}{185.7\text{ km}}\right) = 10.5°$. Since $D_x < 0$ and $D_y > 0$, the direction of $\vec{\boldsymbol{D}}$ is 10.5° west of north.

Reflect: The four displacements add to zero.

Solutions to Passage Problems

***1.57. Set Up:** The total volume is equal to the number of alveoli times the average volume of a single alveolus. Note that $1\,\mu\text{m} = 10^{-6}$ m and $1\text{ m}^3 = 10^3$ L.

Solve: $(480\times10^6\text{ alveoli})\left(\dfrac{4.2\times10^6\ \mu\text{m}^3}{\text{alveolus}}\right)\left(\dfrac{10^{-6}\text{ m}}{1\,\mu\text{m}}\right)^3\left(\dfrac{10^3\text{ L}}{1\text{ m}^3}\right) = 2.0\text{ L}$

The correct answer is C.

1.58. Set Up: The volume of a sphere is $V = \dfrac{4}{3}\pi r^3$. Note that $1\,\mu\text{m} = 10^{-6}\text{ m} = 10^{-3}$ mm.

Solve: Solve for *r* to obtain the diameter of a typical alveolus:

$$d = 2r = 2\left(\frac{3V}{4\pi}\right)^{1/3} = 2\left(\frac{3(4.2\times10^6\ \mu\text{m}^3)}{4\pi}\right)^{1/3}\left(\frac{10^{-3}\text{ mm}}{1\,\mu\text{m}}\right) = 0.20\text{ mm}$$

The correct answer is A.

***1.59. Set Up:** The graph shows a nearly horizontal line, with no systematic upward or downward trend. Thus, the average volume of the alveoli is not dependent on the total lung volume.
Solve: The total lung volume must be equal to the average volume of the alveoli times the number of alveoli; thus, as the total volume of the lungs increases, the volume of the individual alveoli remains constant and the number of alveoli increases.
The correct answer is C.