E1-1 (a) Megaphones; (b) Microphones; (c) Decacards (Deck of Cards); (d) Gigalows (Gigolos); (e) Terabulls (Terribles); (f) Decimates; (g) Centipedes; (h) Nanonanettes (?); (i) Picoboos (Peek-a-Boo); (j) Attoboys ('atta boy); (k) Two Hectowithits (To Heck With It); (l) Two Kilomockingbirds (To Kill A Mockingbird, or Tequila Mockingbird).

E1-2 (a) $\$36,000/52$ week $= \$692$/week. (b) $\$10,000,000/(20 \times 12$ month$) = \$41,700$/month. (c) $30 \times 10^9/8 = 3.75 \times 10^9$.

E1-3 Multiply out the factors which make up a century.

$$1 \text{ century} = 100 \text{ years} \left(\frac{365 \text{ days}}{1 \text{ year}}\right)\left(\frac{24 \text{ hours}}{1 \text{ day}}\right)\left(\frac{60 \text{ minutes}}{1 \text{ hour}}\right)$$

This gives 5.256×10^7 minutes in a century, so a microcentury is 52.56 minutes.

The percentage difference from Fermi's approximation is (2.56 min)/(50 min) $\times$ 100% or 5.12%.

E1-4 (3000 mi)/(3 hr) = 1000 mi/timezone-hour. There are 24 time-zones, so the circumference is approximately 24×1000 mi $= 24,000$ miles.

E1-5 Actual number of seconds in a year is

$$(365.25 \text{ days})\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = 3.1558 \times 10^7 \text{ s}.$$

The percentage error of the approximation is then

$$\frac{3.1416 \times 10^7 \text{ s} - 3.1558 \times 10^7 \text{ s}}{3.1558 \times 10^7 \text{ s}} = -0.45\,\%.$$

E1-6 (a) 10^{-8} seconds per shake means 10^8 shakes per second. There are

$$\left(\frac{365 \text{ days}}{1 \text{ year}}\right)\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = 3.1536 \times 10^7 \text{ s/year}.$$

This means there are more shakes in a second.

(b) Humans have existed for a fraction of

$$10^6 \text{ years}/10^{10} \text{ years} = 10^{-4}.$$

That fraction of a day is

$$10^{-4}\,(24 \text{ hr})\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = 8.64\,\text{s}.$$

E1-7 We'll assume, for convenience only, that the runner with the longer time ran *exactly* one mile. Let the speed of the runner with the shorter time be given by v_1, and call the distance actually ran by this runner d_1. Then $v_1 = d_1/t_1$. Similarly, $v_2 = d_2/t_2$ for the other runner, and $d_2 = 1$ mile.

We want to know when $v_1 > v_2$. Substitute our expressions for speed, and get $d_1/t_1 > d_2/t_2$. Rearrange, and $d_1/d_2 > t_1/t_2$ or $d_1/d_2 > 0.99937$. Then $d_1 > 0.99937$ mile $\times$ (5280 feet/1 mile) or $d_1 > 5276.7$ feet is the condition that the first runner was indeed faster. The first track can be no more than 3.3 feet too short to guarantee that the first runner was faster.

E1-8 We will wait until a day's worth of minutes have been gained. That would be

$$(24 \text{ hr})\left(\frac{60 \text{ min}}{1 \text{ hr}}\right) = 1440 \text{ min}.$$

The clock gains one minute per day, so we need to wait 1,440 days, or almost four years. Of course, if it is an older clock with hands that only read 12 hours (instead of 24), then after only 720 days the clock would be correct.

E1-9 First find the "logarithmic average" by

$$\begin{aligned} \log t_{\text{av}} &= \frac{1}{2}\left(\log(5\times 10^{17}) + \log(6\times 10^{-15})\right), \\ &= \frac{1}{2}\log\left(5\times 10^{17}\times 6\times 10^{-15}\right), \\ &= \frac{1}{2}\log 3000 = \log\left(\sqrt{3000}\right). \end{aligned}$$

Solve, and $t_{\text{av}} = 54.8$ seconds.

E1-10 After 20 centuries the day would have increased in length by a total of $20 \times 0.001\,\text{s} = 0.02\,\text{s}$. The cumulative effect would by the product of the *average* increase and the number of days; that average is half of the maximum, so the cumulative effect is $\frac{1}{2}(2000)(365)(0.02\,\text{s}) = 7300\,\text{s}$. That's about 2 hours.

E1-11 Lunar months are based on the Earth's position, and as the Earth moves around the orbit the Moon has farther to go to complete a phase. In 27.3 days the Moon may have orbited through 360°, but since the Earth moved through $(27.3/365) \times 360° = 27°$ the Moon needs to move 27° farther to catch up. That will take $(27°/360°) \times 27.3$ days $= 2.05$ days, but in that time the Earth would have moved on yet farther, and the moon will need to catch up again. How much farther? $(2.05/365) \times 360° = 2.02°$ which means $(2.02°/360°) \times 27.3$ days $= 0.153$ days. The total so far is 2.2 days longer; we could go farther, but at our accuracy level, it isn't worth it.

E1-12 $(1.9\,\text{m})(3.281 \text{ ft}/1.000\,\text{m}) = 6.2$ ft, or just under 6 feet, 3 inches.

E1-13 (a) 100 meters = 328.1 feet (Appendix G), or $328.1/3 = 10.9$ yards. This is 28 feet longer than 100 yards, or $(28 \text{ ft})(0.3048 \text{ m/ft}) = 8.5\,\text{m}$. (b) A metric mile is $(1500\,\text{m})(6.214\times 10^{-4} \text{ mi/m}) = 0.932$ mi. I'd rather run the metric mile.

E1-14 There are

$$300,000 \text{ years}\left(\frac{365.25 \text{ days}}{1 \text{ year}}\right)\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)\left(\frac{60 \text{ min}}{1 \text{ hr}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right) = 9.5\times 10^{12}\text{s}$$

that will elapse before the cesium clock is in error by 1 s. This is almost 1 part in 10^{13}. This kind of accuracy with respect to 2572 miles is

$$10^{-13}(2572 \text{ mi})\left(\frac{1609\,\text{m}}{1 \text{ mi}}\right) = 413 \text{ nm}.$$

E1-15 The volume of Antarctica is approximated by the area of the base time the height; the area of the base is the area of a semicircle. Then

$$V = Ah = \left(\frac{1}{2}\pi r^2\right) h.$$

The volume is

$$\begin{aligned} V &= \frac{1}{2}(3.14)(2000 \times 1000 \text{ m})^2(3000 \text{ m}) = 1.88 \times 10^{16} \text{ m}^3 \\ &= 1.88 \times 10^{16} \text{ m}^3 \times \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3 = 1.88 \times 10^{22} \text{ cm}^3. \end{aligned}$$

E1-16 The volume is $(77\times 10^4\,\text{m}^2)(26\,\text{m}) = 2.00\times 10^7\,\text{m}^3$. This is equivalent to

$$(2.00\times 10^7 \text{ m}^3)(10^{-3} \text{ km/m})^3 = 0.02 \text{ km}^3.$$

E1-17 (a) $C = 2\pi r = 2\pi(6.37 \times 10^3 \text{ km}) = 4.00 \times 10^4$ km. (b) $A = 4\pi r^2 = 4\pi(6.37 \times 10^3 \text{ km})^2 = 5.10 \times 10^8$ km. (c) $V = \frac{4}{3}\pi(6.37 \times 10^3 \text{ km})^3 = 1.08 \times 10^{12} \text{ km}^3$.

E1-18 The conversions: squirrel, 19 km/hr(1000 m/km)/(3600 s/hr) = 5.3 m/s;
rabbit, 30 knots(1.688ft/s/knot)(0.3048 m/ft) = 15 m/s;
snail, 0.030 mi/hr(1609 m/mi)/(3600 s/hr) = 0.013 m/s;
spider, 1.8 ft/s(0.3048 m/ft) = 0.55 m/s;
cheetah, 1.9 km/min(1000 m/km)/(60 s/min) = 32 m/s;
human, 1000 cm/s/(100 cm/m) = 10 m/s;
fox, 1100 m/min/(60 s/min) = 18 m/s;
lion, 1900 km/day(1000 m/km)/(86, 400 s/day) = 22 m/s.
The order is snail, spider, squirrel, human, rabbit, fox, lion, cheetah.

E1-19 One light-year is the distance traveled by light in one year, or $(3 \times 10^8 \text{ m/s}) \times (1 \text{ year})$. Then

$$19,200\frac{\text{mi}}{\text{hr}}\left(\frac{\text{light-year}}{(3 \times 10^8 \text{ m/s}) \times (1 \text{ year})}\right)\left(\frac{1609 \text{ m}}{1 \text{ mi}}\right)\left(\frac{1 \text{ hr}}{3600 \text{ s}}\right)\left(\frac{100 \text{ year}}{1 \text{ century}}\right),$$

which is equal to 0.00286 light-year/century.

E1-20 Start with the British units inverted,

$$\frac{\text{gal}}{30.0 \text{ mi}}\left(\frac{231 \text{ in}^3}{\text{gal}}\right)\left(\frac{1.639 \times 10^{-2} \text{ L}}{\text{in}^3}\right)\left(\frac{\text{mi}}{1.609 \text{ km}}\right) = 7.84 \times 10^{-2} \text{ L/km}.$$

E1-21 (b) A light-year is

$$(3.00 \times 10^5 \text{ km/s})\left(\frac{3600 \text{ s}}{1 \text{ hr}}\right)\left(\frac{24 \text{ hr}}{1 \text{ day}}\right)(365 \text{ days}) = 9.46 \times 10^{12} \text{ km}.$$

A parsec is

$$\frac{1.50 \times 10^8 \text{ km}}{0^\circ\, 0'\, 1''}\left(\frac{360^\circ}{2\pi \text{ rad}}\right) = \frac{1.50 \times 10^8 \text{ km}}{(1/3600)^\circ}\left(\frac{360^\circ}{2\pi \text{ rad}}\right) = 3.09 \times 10^{13} \text{ km}.$$

(a) $(1.5 \times 10^8 \text{ km})/(3.09 \times 10^{13} \text{ km/pc} = 4.85 \times 10^{-6}$ pc. $(1.5 \times 10^8 \text{ km})/(9.46 \times 10^{12} \text{ km/ly}) = 1.59 \times 10^{-5}$ ly.

E1-22 First find the "logarithmic average" by

$$\begin{aligned}\log d_{\text{av}} &= \frac{1}{2}\left(\log(2\times 10^{26})+\log(1\times 10^{-15})\right),\\ &= \frac{1}{2}\log\left(2\times 10^{26}\times 1\times 10^{-15}\right),\\ &= \frac{1}{2}\log 2\times 10^{11} = \log\left(\sqrt{2\times 10^{11}}\right).\end{aligned}$$

Solve, and $d_{\text{av}} = 450$ km.

E1-23 The number of atoms is given by (1 kg)/($1.00783\times 1.661\times 10^{-27}$ kg), or 5.974×10^{26} atoms.

E1-24 (a) $(2\times 1.0+16)\text{u}(1.661\times 10^{-27}\text{kg}) = 3.0\times 10^{-26}\text{kg}$.
(b) $(1.4\times 10^{21}\text{kg})/(3.0\times 10^{-26}\text{kg}) = 4.7\times 10^{46}$ molecules.

E1-25 The coffee in Paris costs \$18.00 per kilogram, or

$$\$18.00\ \text{kg}^{-1}\left(\frac{0.4536\ \text{kg}}{1\ \text{lb}}\right) = \$8.16\ \text{lb}^{-1}.$$

It is cheaper to buy coffee in New York (at least according to the physics textbook, that is.)

E1-26 The room volume is $(21\times 13\times 12)\text{ft}^3(0.3048\ \text{m/ft})^3 = 92.8\,\text{m}^3$. The mass contained in the room is

$$(92.8\,\text{m}^3)(1.21\,\text{kg/m}^3) = 112\,\text{kg}.$$

E1-27 One mole of sugar cubes would have a volume of $N_A\times 1.0\ \text{cm}^3$, where N_A is the Avogadro constant. Since the volume of a cube is equal to the length cubed, $V = l^3$, then $l = \sqrt[3]{N_A}$ cm $= 8.4\times 10^7$ cm.

E1-28 The number of seconds in a week is $60\times 60\times 24\times 7 = 6.05\times 10^5$. The "weight" loss per second is then

$$(0.23\,\text{kg})/(6.05\times 10^5\,\text{s}) = 3.80\times 10^{-1}\ \text{mg/s}.$$

E1-29 The definition of the meter was wavelengths per meter; the question asks for meters per wavelength, so we want to take the reciprocal. The definition is accurate to 9 figures, so the reciprocal should be written as $1/1,650,763.73 = 6.05780211\times 10^{-7}\,\text{m} = 605.780211$ nm.

E1-30 (a) $37.76+0.132 = 37.89$. (b) $16.264-16.26325 = 0.001$.

E1-31 The easiest approach is to first solve Darcy's Law for K, and then substitute the known SI units for the other quantities. Then

$$K = \frac{VL}{AHt}\ \text{has units of}\ \frac{(\text{m}^3)\,(\text{m})}{(\text{m}^2)\,(\text{m})\,(\text{s})}$$

which can be simplified to m/s.

E1-32 The Planck length, l_P, is found from

$$\begin{aligned}[l_\mathrm{P}] &= [c^i][G^j][h^k],\\ \mathrm{L} &= (\mathrm{LT}^{-1})^i(\mathrm{L}^3\mathrm{T}^{-2}\mathrm{M}^{-1})^j(\mathrm{ML}^2\mathrm{T}^{-1})^k,\\ &= \mathrm{L}^{i+3j+2k}\mathrm{T}^{-i-2j-k}\mathrm{M}^{-j+k}.\end{aligned}$$

Equate powers on each side,

$$\begin{aligned}\mathrm{L}\!: 1 &= i+3j+2k,\\ \mathrm{T}\!: 0 &= -i-2j-k,\\ \mathrm{M}\!: 0 &= -j+k.\end{aligned}$$

Then $j = k$, and $i = -3k$, and $1 = 2k$; so $k = 1/2$, $j = 1/2$, and $i = -3/2$. Then

$$\begin{aligned}[l_\mathrm{P}] &= [c^{-3/2}][G^{1/2}][h^{1/2}],\\ &= (3.00\times10^{8}\,\mathrm{m/s})^{-3/2}(6.67\times10^{-11}\,\mathrm{m^3/s^2\cdot kg})^{1/2}(6.63\times10^{-34}\,\mathrm{kg\cdot m^2/s})^{1/2},\\ &= 4.05\times10^{-35}\,\mathrm{m}.\end{aligned}$$

E1-33 The Planck mass, m_P, is found from

$$\begin{aligned}[m_\mathrm{P}] &= [c^i][G^j][h^k],\\ \mathrm{M} &= (\mathrm{LT}^{-1})^i(\mathrm{L}^3\mathrm{T}^{-2}\mathrm{M}^{-1})^j(\mathrm{ML}^2\mathrm{T}^{-1})^k,\\ &= \mathrm{L}^{i+3j+2k}\mathrm{T}^{-i-2j-k}\mathrm{M}^{-j+k}.\end{aligned}$$

Equate powers on each side,

$$\begin{aligned}\mathrm{L}\!: 0 &= i+3j+2k,\\ \mathrm{T}\!: 0 &= -i-2j-k,\\ \mathrm{M}\!: 1 &= -j+k.\end{aligned}$$

Then $k = j+1$, and $i = -3j-1$, and $0 = -1+2k$; so $k = 1/2$, and $j = -1/2$, and $i = 1/2$. Then

$$\begin{aligned}[m_\mathrm{P}] &= [c^{1/2}][G^{-1/2}][h^{1/2}],\\ &= (3.00\times10^{8}\,\mathrm{m/s})^{1/2}(6.67\times10^{-11}\,\mathrm{m^3/s^2\cdot kg})^{-1/2}(6.63\times10^{-34}\,\mathrm{kg\cdot m^2/s})^{1/2},\\ &= 5.46\times10^{-8}\,\mathrm{kg}.\end{aligned}$$

P1-1 There are $24\times60 = 1440$ traditional minutes in a day. The conversion plan is then fairly straightforward

$$822.8\ \text{dec. min}\left(\frac{1440\ \text{trad. min}}{1000\ \text{dec. min}}\right) = 1184.8\ \text{trad. min}.$$

This is traditional minutes since midnight, the time in traditional hours can be found by dividing by 60 min/hr, the integer part of the quotient is the hours, while the remainder is the minutes. So the time is 19 hours, 45 minutes, which would be 7:45 pm.

P1-2 (a) By similar triangles, the ratio of the distances is the same as the ratio of the diameters—390:1.

(b) Volume is proportional to the radius (diameter) cubed, or $390^3 = 5.93\times10^7$.

(c) $0.52^\circ(2\pi/360^\circ) = 9.1\times10^{-3}$ rad. The diameter is then $(9.1\times10^{-3}\ \text{rad})(3.82\times10^5\ \text{km}) = 3500$ km.

P1-3 (a) The circumference of the Earth is approximately 40,000 km; 0.5 seconds of an arc is $0.5/(60 \times 60 \times 360) = 3.9 \times 10^{-7}$ of a circumference, so the north-south error is $\pm(3.9 \times 10^{-7})(4 \times 10^7\,\mathrm{m}) = \pm 15.6\,\mathrm{m}$. This is a range of 31 m.

(b) The east-west range is smaller, because the distance measured along a latitude is smaller than the circumference by a factor of the cosine of the latitude. Then the range is $31 \cos 43.6^\circ = 22\,\mathrm{m}$.

(c) The tanker is in Lake Ontario, some 20 km off the coast of Hamlin?

P1-4 Your position is determined by the time it takes for your longitude to rotate "underneath" the sun (in fact, that's the way longitude was measured originally as in 5 hours west of the Azores...) the rate the sun sweep over at equator is 25,000 miles/86,400 s = 0.29 miles/second. The correction factor because of latitude is the cosine of the latitude, so the sun sweeps overhead near England at approximately 0.19 mi/s. Consequently a 30 mile accuracy requires an error in time of no more than (30 mi)/(0.19 mi/s) = 158 seconds.

Trip takes about 6 months, so clock accuracy needs to be within $(158\,\mathrm{s})/(180\ \mathrm{day}) = 1.2$ seconds/day.

(b) Same, except 0.5 miles accuracy requires 2.6 s accuracy, so clock needs to be within 0.007 s/day!

P1-5 Let B be breaths/minute while sleeping. Each breath takes in (1.43 g/L)(0.3 L) = 0.429 g; and lets out (1.96 g/L)(0.3 L) = 0.288 g. The net loss is 0.141 g. Multiply by the number of breaths, (8 hr)(60 min./hr)B(0.141 g) = B(67.68 g). I'll take a short nap, and count my breaths, then finish the problem.

I'm back now, and I found my breaths to be 8/minute. So I lose 541 g/night, or about 1 pound.

P1-6 The mass of the water is $(1000\,\mathrm{kg/m^3})(5700\,\mathrm{m^3}) = 5.7 \times 10^6\,\mathrm{kg}$. The rate that water leaks drains out is

$$\frac{(5.7 \times 10^6\,\mathrm{kg})}{(12\ \mathrm{hr})(3600\ \mathrm{s/hr})} = 132\,\mathrm{kg/s}.$$

P1-7 Let the radius of the grain be given by r_g. Then the surface area of the grain is $A_g = 4\pi r_g^2$, and the volume is given by $V_g = (4/3)\pi r_g^3$.

If N grains of sand have a total surface area equal to that of a cube 1 m on a edge, then $NA_g = 6\ \mathrm{m}^2$. The total volume V_t of this number of grains of sand is NV_g. Eliminate N from these two expressions and get

$$V_t = NV_g = \frac{(6\ \mathrm{m}^2)}{A_g} V_g = \frac{(6\ \mathrm{m}^2) r_g}{3}.$$

Then $V_t = (2\ \mathrm{m}^2)(50 \times 10^{-6}\ \mathrm{m}) = 1 \times 10^{-4}\ \mathrm{m}^3$.

The mass of a volume V_t is given by

$$1 \times 10^{-4}\ \mathrm{m}^3 \left(\frac{2600\ \mathrm{kg}}{1\ \mathrm{m}^3}\right) = 0.26\ \mathrm{kg}.$$

P1-8 For a cylinder $V = \pi r^2 h$, and $A = 2\pi r^2 + 2\pi r h$. We want to minimize A with respect to changes in r, so

$$\begin{aligned} \frac{dA}{dr} &= \frac{d}{dr}\left(2\pi r^2 + 2\pi r \frac{V}{\pi r^2}\right), \\ &= 4\pi r - 2\frac{V}{r^2}. \end{aligned}$$

Set this equal to zero; then $V = 2\pi r^3$. Notice that $h = 2r$ in this expression.

P1-9 (a) The volume per particle is

$$(9.27 \times 10^{-26}\text{kg})/(7870\,\text{kg/m}^3) = 1.178 \times 10^{-28}\text{m}^3.$$

The radius of the corresponding sphere is

$$r = \sqrt[3]{\frac{3(1.178 \times 10^{-28}\text{m}^3)}{4\pi}} = 1.41 \times 10^{-10}\text{m}.$$

Double this, and the spacing is 282 pm.

(b) The volume per particle is

$$(3.82 \times 10^{-26}\text{kg})/(1013\,\text{kg/m}^3) = 3.77 \times 10^{-29}\text{m}^3.$$

The radius of the corresponding sphere is

$$r = \sqrt[3]{\frac{3(3.77 \times 10^{-29}\text{m}^3)}{4\pi}} = 2.08 \times 10^{-10}\text{m}.$$

Double this, and the spacing is 416 pm.

P1-10 (a) The area of the plate is (8.43 cm)(5.12 cm) = 43.2 cm^2. (b) (3.14)(3.7 cm)^2 = 43 cm^2.