Problem 1.1 Express the fractions $\frac{1}{3}$ and $\frac{2}{3}$ to three significant digits.

Solution:

$1/3 = 0.3333.. = 0.333$

$2/3 = 0.6666.. = 0.667$

Problem 1.2 The base of natural logarithms is $e = 2.718281828\ldots$

(a) Express e to five significant digits.
(b) Determine the value of e^2 to five significant digits.
(c) Use the value of e you obtained in part (a) to determine the value of e^2 to five significant digits.

[Part (c) demonstrates the hazard of using rounded-off values in calculations.]

Solution: The value of e is: $e = 2.718281828$

(a) To five significant figures $\boxed{e = 2.7183}$

(b) e^2 to five significant figures is $\boxed{e^2 = 7.3891}$

(c) Using the value from part (a) we find $\boxed{e^2 = 7.3892}$ which is not correct in the fifth digit.

Problem 1.3 A machinist drills a circular hole in a panel with radius $r = 5$ mm. Determine the circumference C and area A of the hole to four significant digits.

Solution:

$$C = 2\pi r = 10\pi = 31.42 \text{ mm}$$

$$A = \pi r^2 = 25\pi = 78.54 \text{ mm}^2$$

Problem 1.4 The opening in a soccer goal is 24 ft wide and 8 ft high. Use these values to determine its dimensions in meters to three significant digits.

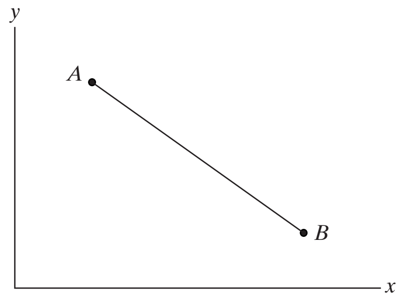
Solution: The conversion between feet and meters, found inside the front cover of the textbook, is 1 m = 3.281 ft. The goal width,

$$w = 24 \text{ ft} \left(\frac{1 \text{ m}}{3.281 \text{ ft}} \right) = 7.3148 \text{ m} = 7.31 \text{ m}.$$

The goal height is given by

$$h = 8 \text{ ft} \left(\frac{1 \text{ m}}{3.281 \text{ ft}} \right) = 2.438 \text{ m} = 2.44 \text{ m}.$$

Problem 1.5 The coordinates (in meters) of point A are $x_A = 3$, $y_A = 7$, and the coordinates of point B are $x_B = 10$, $y_B = 2$. Determine the length of the straight line from A to B to three significant digits.



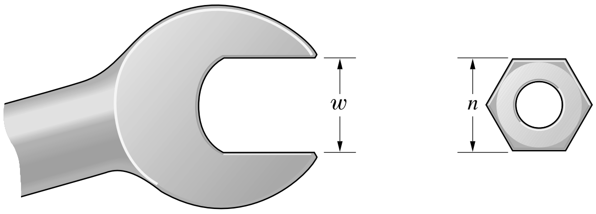
Solution: The length is

$$L = \sqrt{(10-3)^2 + (2-7)^2} \text{ m} = \sqrt{74} \text{ m} = 8.602325 \text{ m}$$

to three significant figures this is

$$\boxed{L = 8.60 \text{ m}}$$

Problem 1.6 Suppose that you have just purchased a Ferrari F355 coupe and you want to know whether you can use your set of SAE (U.S. Customary Units) wrenches to work on it. You have wrenches with widths $w = 1/4$ in, 1/2 in, 3/4 in, and 1 in, and the car has nuts with dimensions $n = 5$ mm, 10 mm, 15 mm, 20 mm, and 25 mm. Defining a wrench to fit if w is no more than 2% larger than n, which of your wrenches can you use?



Solution: Convert the metric size n to inches, and compute the percentage difference between the metric sized nut and the SAE wrench. The results are:

$$5 \text{ mm}\left(\frac{1 \text{ inch}}{25.4 \text{ mm}}\right) = 0.19685.. \text{ in}, \quad \left(\frac{0.19685 - 0.25}{0.19685}\right)100$$

$$= -27.0\%$$

$$10 \text{ mm}\left(\frac{1 \text{ inch}}{25.4 \text{ mm}}\right) = 0.3937.. \text{ in}, \quad \left(\frac{0.3937 - 0.5}{0.3937}\right)100 = -27.0\%$$

$$15 \text{ mm}\left(\frac{1 \text{ inch}}{25.4 \text{ mm}}\right) = 0.5905.. \text{ in}, \quad \left(\frac{0.5905 - 0.5}{0.5905}\right)100 = +15.3\%$$

$$20 \text{ mm}\left(\frac{1 \text{ inch}}{25.4 \text{ mm}}\right) = 0.7874.. \text{ in}, \quad \left(\frac{0.7874 - 0.75}{0.7874}\right)100 = +4.7\%$$

$$25 \text{ mm}\left(\frac{1 \text{ inch}}{25.4 \text{ mm}}\right) = 0.9843.. \text{ in}, \quad \left(\frac{0.9843 - 1.0}{0.9843}\right)100 = -1.6\%$$

A negative percentage implies that the metric nut is smaller than the SAE wrench; a positive percentage means that the nut is larger then the wrench. Thus within the definition of the 2% fit, the 1 in wrench will fit the 25 mm nut. **The other wrenches cannot be used.**

Problem 1.7 On August 20, 1974, Nolan Ryan threw the first baseball pitch measured at over 100 mi/h. The measured speed was 100.9 mi/h. Determine the speed of the pitch to four significant digits (a) in ft/s; (b) in km/h.

Solution:

(a) $$\boxed{v = 100.9\frac{\text{mi}}{\text{h}}\left(\frac{5280\text{ ft}}{1\text{ mi}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right) = 148.0\frac{\text{ft}}{\text{s}}}$$

(b) $$\boxed{\begin{aligned} v &= 100.9\frac{\text{mi}}{\text{h}}\left(\frac{5280\text{ ft}}{\text{mi}}\right)\left(\frac{0.3048\text{ m}}{\text{ft}}\right)\left(\frac{1\text{ km}}{1000\text{ m}}\right) \\ &= 162.4\text{ km/h}\end{aligned}}$$

Problem 1.8 On March 18, 1999, an experimental Maglev (magnetic levitation) train in Japan reached a maximum speed of 552 km/h. What was its velocity in mi/h to three significant digits?

Solution:

$$\boxed{v = 552\frac{\text{km}}{\text{h}}\left(\frac{1000\ \text{m}}{\text{km}}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)\left(\frac{1\ \text{mi}}{5280\ \text{ft}}\right) = 343\ \text{mi/h}}$$

Problem 1.9 In May, 1963, in the last flight of Project Mercury, Astronaut L. Gordon Cooper traveled a distance of 546,167 miles in 1 day, 10 hours, 19 minutes, and 49 seconds. Determine his average speed (the distance traveled divided by the time required) to three significant digits (a) in mi/h; (b) in km/h.

Solution:

(a) $$\boxed{v = \frac{546167 \text{ mi}}{\left(34 + \frac{19}{60} + \frac{49}{3600}\right) \text{h}} = 15{,}900 \text{ mi/h}}$$

(b) $$\boxed{\begin{aligned} v &= 15{,}900 \frac{\text{mi}}{\text{h}} \left(\frac{5280 \text{ ft}}{1 \text{ mi}}\right)\left(\frac{0.3048 \text{ m}}{\text{ft}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) \\ &= 25{,}600 \text{ km/h} \end{aligned}}$$

Problem 1.10 Engineers who study shock waves sometimes express velocity in millimeters per microsecond (mm/μs). Suppose the velocity of a wavefront is measured and determined to be 5 mm/μs. Determine its velocity: (a) in m/s; (b) in mi/s.

Solution: Convert units using Tables 1.1 and 1.2. The results:

(a) $$5\left(\frac{\text{mm}}{\mu\text{s}}\right)\left(\frac{1\text{ m}}{1000\text{ mm}}\right)\left(\frac{10^6\ \mu\text{s}}{1\text{ s}}\right) = 5000\left(\frac{\text{m}}{\text{s}}\right).$$

Next, use this result to get (b):

(b) $$5000\left(\frac{\text{m}}{\text{s}}\right)\left(\frac{1\text{ ft}}{0.3048\text{ m}}\right)\left(\frac{1\text{ mi}}{5280\text{ ft}}\right) = 3.10685\ldots\left(\frac{\text{mi}}{\text{s}}\right)$$

$$= 3.11\left(\frac{\text{mi}}{\text{s}}\right)$$

Problem 1.11 The kinetic energy of a particle of mass m is defined to be $\frac{1}{2}\ mv^2$, where v is the magnitude of the particle's velocity. If the value of the kinetic energy of a particle at a given time is 200 when m is in kilograms and v is in meters per second, what is the value when m is in slugs and v is in feet per second?

Solution:

$$\left(200\ \frac{\text{kg-m}^2}{\text{s}^2}\right)\left(\frac{0.0685\ \text{slug}}{1\ \text{kg}}\right)\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)^2$$

$$= 147.46 = 147\ \frac{\text{slug-ft}^2}{\text{s}^2}$$

Problem 1.12 The acceleration due to gravity at sea level in SI units is $g = 9.81$ m/s^2. By converting units, use this value to determine the acceleration due to gravity at sea level in U.S. Customary units.

Solution: Use Table 1.2. The result is:

$$g = 9.81\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right)\left(\frac{1\ \mathrm{ft}}{0.3048\ \mathrm{m}}\right) = 32.185\ldots\left(\frac{\mathrm{ft}}{\mathrm{s}^2}\right) = 32.2\left(\frac{\mathrm{ft}}{\mathrm{s}^2}\right)$$

Problem 1.13 A *furlong per fortnight* is a facetious unit of velocity, perhaps made up by a student as a satirical comment on the bewildering variety of units engineers must deal with. A furlong is 660 ft (1/8 mile). A fortnight is 2 weeks (14 days). If you walk to class at 2 m/s, what is your speed in furlongs per fortnight to three significant digits?

Solution: Convert the units using the given conversions. Record the first three digits on the left, and add zeros as required by the number of tens in the exponent. The result is:

$$\left(5\ \frac{\text{ft}}{\text{s}}\right)\left(\frac{1\ \text{furlong}}{660\ \text{ft}}\right)\left(\frac{3600\ \text{s}}{1\ \text{hr}}\right)\left(\frac{24\ \text{hr}}{1\ \text{day}}\right)\left(\frac{14\ \text{day}}{1\ \text{fortnight}}\right)$$

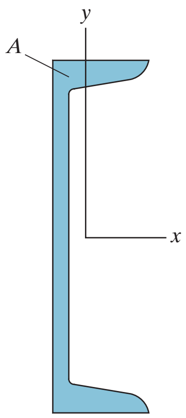
$$=\left(9160\ \frac{\text{furlongs}}{\text{fortnight}}\right)$$

Problem 1.14 The cross-sectional area of a beam is 480 in^2. What is its cross-section in m^2?

Solution: Convert units using Table 1.2. The result:

$$480\ \text{in}^2 \left(\frac{1\ \text{ft}}{12\ \text{in}}\right)^2 \left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right)^2 = 0.30967\ldots \text{m}^2 = 0.310\ \text{m}^2$$

Problem 1.15 The cross-sectional area of the C12×30 American Standard Channel steel beam is $A = 8.81\ \text{in}^2$. What is its cross-sectional area in mm^2?



Solution:

$$\boxed{A = 8.81\ \text{in}^2 \left(\frac{25.4\ \text{mm}}{1\ \text{in}}\right)^2 = 5680\ \text{mm}^2}$$

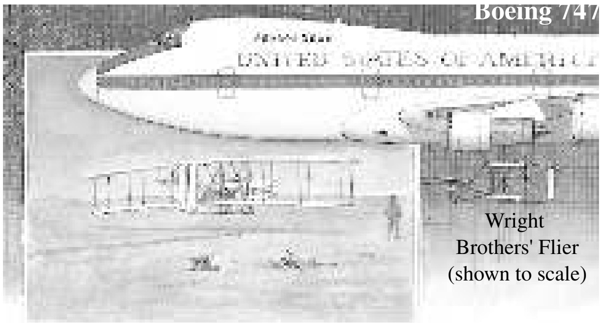
Problem 1.16 A pressure transducer measures a value of 300 lb/in^2. Determine the value of the pressure in pascals. A pascal (Pa) is one newton per meter squared.

Solution: Convert the units using Table 1.2 and the definition of the Pascal unit. The result:

$$300\left(\frac{\text{lb}}{\text{in}^2}\right)\left(\frac{4.448\ \text{N}}{1\ \text{lb}}\right)\left(\frac{12\ \text{in}}{1\ \text{ft}}\right)^2\left(\frac{1\ \text{ft}}{0.3048\ \text{m}}\right)^2$$

$$= 2.0683\ldots(10^6)\left(\frac{\text{N}}{\text{m}^2}\right) = 2.07(10^6)\ \text{Pa}$$

Problem 1.17 A horsepower is 550 ft-lb/s. A watt is 1 N-m/s. Determine the number of watts generated by (a) the Wright brothers' 1903 airplane, which had a 12-horsepower engine; (b) a modern passenger jet with a power of 100,000 horsepower at cruising speed.



Solution: Convert units using inside front cover of textbook derive the conversion between horsepower and watts. The result

(a) $12 \text{ hp} \left(\dfrac{746 \text{ watt}}{1 \text{ hp}}\right) = 8950 \text{ watt}$

(b) $10^5 \text{ hp} \left(\dfrac{746 \text{ watt}}{1 \text{ hp}}\right) = 7.46(10^7) \text{ watt}$

Problem 1.18 In SI units, the universal gravitational constant $G = 6.67 \times 10^{-11}$ N-m^2/kg^2. Determine the value of G in U.S. Customary units.

Solution: Convert units using Table 1.2. The result:

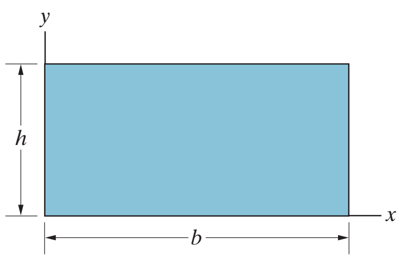
$$6.67(10^{-11})\left(\frac{\text{N-m}^2}{\text{kg}^2}\right)\left(\frac{1\text{ lb}}{4.448\text{ N}}\right)\left(\frac{1\text{ ft}}{0.3048\text{ m}}\right)^2\left(\frac{14.59\text{ kg}}{1\text{ slug}}\right)^2$$

$$= 3.43590\ldots(10^{-8})\left(\frac{\text{lb-ft}^2}{\text{slug}^2}\right) = 3.44(10^{-8})\left(\frac{\text{lb-ft}^2}{\text{slug}^2}\right)$$

Problem 1.19 The moment of inertia of the rectangular area about the x axis is given by the equation

$$I = \tfrac{1}{3}bh^3.$$

The dimensions of the area are $b = 200$ mm and $h = 100$ mm. Determine the value of I to four significant digits in terms of (a) mm^4; (b) m^4; (c) in^4.



Solution:

(a) $\boxed{I = \frac{1}{3}(200\text{ mm})(100\text{ mm})^3 = 66.7 \times 10^6\text{ mm}^4}$

(b) $\boxed{I = 66.7 \times 10^6\text{ mm}^4 \left(\frac{1\text{ m}}{1000\text{ mm}}\right)^4 = 66.7 \times 10^{-6}\text{ m}^4}$

(c) $\boxed{I = 66.7 \times 10^6\text{ mm}^4 \left(\frac{1\text{ in}}{25.4\text{ mm}}\right)^4 = 160\text{ in}^4}$

Problem 1.20 In the equation

$T = \frac{1}{2}I\omega^2$,

the term I is in kg-m^2 and ω is in s^{-1}.

(a) What are the SI units of T?
(b) If the value of T is 100 when I is in kg-m^2 and ω is in s^{-1}, what is the value of T when it is expressed in U.S. Customary base units?

Solution: For (a), substitute the units into the expression for T:

(a) $$T = \left(\frac{1}{2}\right)(I \text{ kg-m}^2)(\omega \text{s}^{-1})^2 = \frac{\text{kg-m}^2}{\text{s}^2}$$

For (b), convert units using Table 1.2. The result:

(b) $$100\left(\frac{\text{kg-m}^2}{\text{s}^2}\right)\left(\frac{1 \text{ slug}}{14.59 \text{ kg}}\right)\left(\frac{1 \text{ ft}}{0.3048 \text{ m}}\right)^2$$

$$= 73.7759\ldots\left(\frac{\text{slug-ft}^2}{\text{s}^2}\right) = 73.8\left(\frac{\text{slug-ft}^2}{\text{s}^2}\right)$$

Problem 1.21 The equation

$$\sigma = \frac{My}{I}$$

is used in the mechanics of materials to determine normal stresses in beams.

(a) When this equation is expressed in terms of SI base units, M is in newton-meters (N-m), y is in meters (m), and I is in meters to the fourth power (m^4). What are the SI units of σ?

(b) If $M = 2000$ N-m, $y = 0.1$ m, and $I = 7 \times 10^{-5}$ m^4, what is the value of σ in U.S. Customary base units?

Solution:

(a) $$\boxed{\sigma = \frac{My}{I} = \frac{(\text{N-m})\text{m}}{\text{m}^4} = \frac{\text{N}}{\text{m}^2}}$$

(b) $$\boxed{\begin{aligned}\sigma &= \frac{My}{I} = \frac{(2000\ \text{N-m})(0.1\ \text{m})}{7 \times 10^{-5}\ \text{m}^4}\left(\frac{1\ \text{lb}}{4.448\ \text{N}}\right)\left(\frac{0.3048\ \text{m}}{\text{ft}}\right)^2 \\ &= 59{,}700\,\frac{\text{lb}}{\text{ft}^2}\end{aligned}}$$

Problem 1.22 Let W be your weight at sea level in pounds. (a) What is your weight at sea level in newtons? (b) What is your mass in kilograms?

Solution:

(a) $\boxed{W\ (\text{lb})\left(\frac{4.448\ \text{N}}{\text{lb}}\right) = 4.448W\ (\text{N})}$

(b) $\boxed{m = \frac{4.448W\ (\text{N})}{9.81\ \text{m/s}^2} = 0.453W\ (\text{kg})}$

Problem 1.23 The acceleration due to gravity is 1.62 m/s^2 on the surface of the moon and 9.81 m/s^2 on the surface of the earth. A female astronaut's mass is 57 kg. What is the maximum allowable mass of her spacesuit and equipment if the engineers don't want the total weight on the moon of the woman, her spacesuit and equipment to exceed 180 N?

Solution: Find the mass which weighs 180 N on the moon.

$$m = \frac{w}{g} = \frac{180 \text{ N-s}^2}{1.62 \text{ m}} = 111.1 \text{ kg}$$

This is the total allowable mass. Thus, the suit & equipment can have mass of

$$m_{\text{S/E}} = 111.1 \text{ kg} - 57 \text{ kg} = 54.1 \text{ kg}$$

Problem 1.24 A person has a mass of 50 kg.

(a) The acceleration due to gravity at sea level is $g = 9.81\ \mathrm{m/s^2}$. What is the person's weight at sea level?
(b) The acceleration due to gravity on the moon is $g = 1.62\ \mathrm{m/s^2}$. What would the person weigh on the moon?

Solution: Use Eq (1.6).

(a) $W_e = 50\ \mathrm{kg}\left(9.81\ \dfrac{\mathrm{m}}{\mathrm{s^2}}\right) = 490.5\ \mathrm{N} = 491\ \mathrm{N}$, and

(b) $W_{\mathrm{moon}} = 50\ \mathrm{kg}\left(1.62\ \dfrac{\mathrm{m}}{\mathrm{s^2}}\right) = 81\ \mathrm{N}$.

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