

Chapter 1 Problems

1.1 The micrometer is often called the micron. (a) How many microns make up 1 km? (b) What fraction of a centimeter equals $1\mu m$? (c) How many microns are in 1.0 yard

We begin by calculating 1 km in microns

$$d = 1.0km \cdot \frac{1000m}{1km} \cdot \frac{1micron}{1 \times 10^{-6}m} = 1 \times 10^9 microns$$

Now calculate a distance of 1 micron in cm.

$$d = 1micron \cdot \frac{1 \times 10^{-6}m}{1micron} \cdot \frac{100cm}{1m} = 1 \times 10^{-4} cm$$

Finally we compute a distance of 1 yard in microns.

$$d = 1yd \cdot \frac{3ft}{1yd} \cdot \frac{0.3048m}{1ft} \cdot \frac{1micron}{1 \times 10^{-6}m} = 9.144 \times 10^5 microns$$

1.3 Horses are to race over a certain English meadow for a distance of 4 furlongs. What is the race distance in units of (a) rods and (b) chains? (1 furlong = 201.168m, 1 rod = 5.0292 m and 1 chain = 20.117)

$$d = 4 furlongs \cdot \frac{201.168m}{1 furlong} = 8.04672 \times 10^2 m$$

$$d = 8.04672 \times 10^2 m \cdot \frac{1rod}{5.0292m} = 160 rods$$

$$d = 8.04672 \times 10^2 m \cdot \frac{1chain}{20.117} = 40 chains$$

1.5 The Earth is approximately a sphere of radius 6.37×10^6 m. (a) What is its circumference in kilometers? (b) What is its surface area in square kilometers? (c) What is its volume in cubic kilometers?

To do all three sections of this problem, we can first convert the radius to kilometers.

$$r = 6.37 \times 10^6 m \cdot \frac{1km}{1000m} = 6.37 \times 10^3 km$$

(a) The formula for circumference can be found in most calculus books (and in Appendix E of your Physics text). We will assume that we are finding the circumference of the equator.

$$c = 2\pi r = 2\pi \cdot 6.37 \times 10^3 \text{ km} = 4.002 \times 10^4 \text{ km}$$

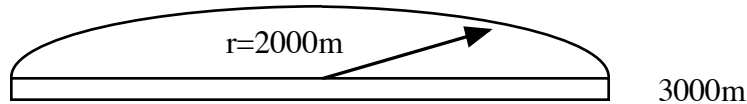
(b) The surface area of a sphere is:

$$a = 4\pi r^2 = 4\pi \cdot (6.37 \times 10^3 \text{ km})^2 = 5.099 \times 10^8 \text{ km}^2$$

(c) The volume of a sphere is:

$$v = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \cdot (6.37 \times 10^3 \text{ km})^3 = 1.083 \times 10^{12} \text{ km}^3$$

1.7 Antarctica is roughly semicircular, with a radius of 2000 km. The average thickness of its ice cover is 3000m. How many cubic centimeters of ice does Antarctica contain? (Ignore the curvature of the earth)



We find the volume in cubic meters first and then convert.

$$\begin{aligned} \text{Volume} &= (\text{Area of half circle}) \cdot (\text{depth}) \\ &= \frac{\pi r^2}{2} \cdot d \\ &= \frac{\pi (2000 \times 10^3 \text{ m})^2}{2} \cdot 3000 \text{ m} = 1.885 \times 10^{16} \text{ m}^3 \\ &= 1.885 \times 10^{16} \text{ m}^3 \cdot \left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3 \\ &= 1.885 \times 10^{22} \text{ cm}^3 \end{aligned}$$

1.9 Hydraulic engineers often use, as a unit of volume of water, the acre-foot, defined as the volume of water that will cover 1 acre of land to a depth of 1 ft. A severe thunderstorm dumps 2.0 inches of rain in 30 min. on a town of area 26 km². What volume of water in acre-feet, fell on the town?

We first convert the depth to feet and the area to acres.

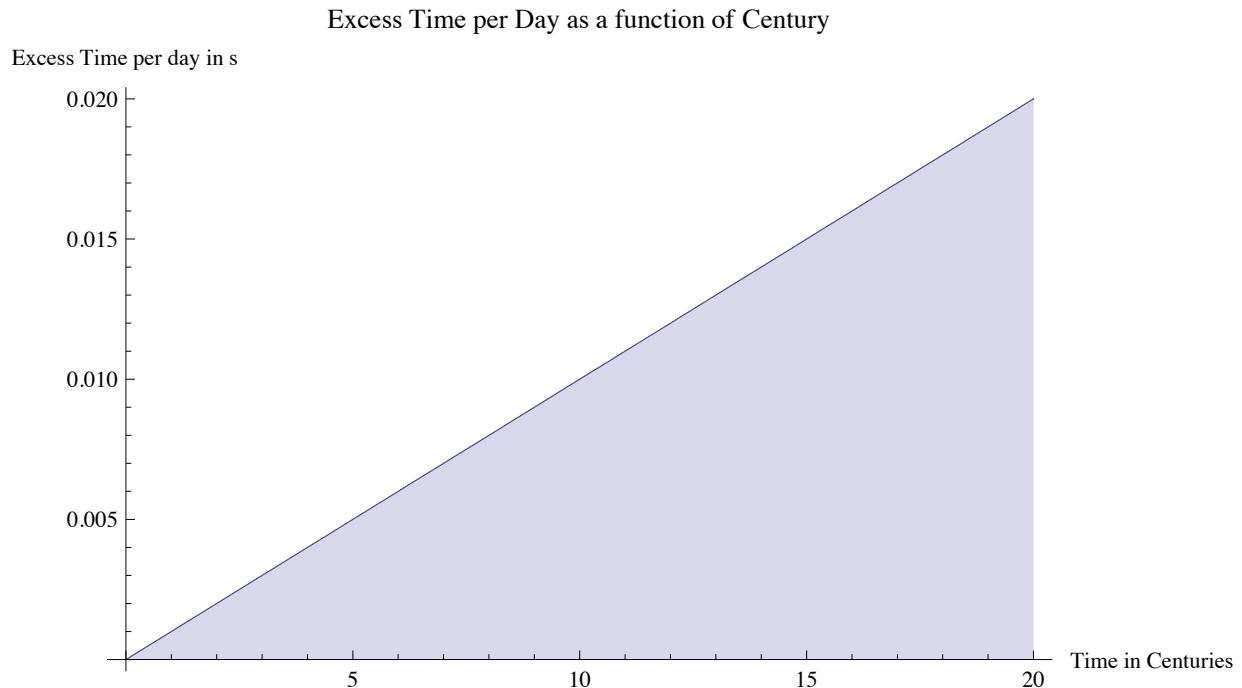
$$d = 2.0 \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} = 0.1667 \text{ ft}$$

$$a = 26 \text{ km}^2 \cdot \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)^2 \cdot \frac{2.471 \text{ acres}}{10^4 \text{ m}^2} = 6.4245 \times 10^3 \text{ acres}$$

$$\text{Volume} = a \cdot d = 6.4245 \times 10^3 \text{ acres} \cdot 0.1667 \text{ ft}$$

$$= 1.071 \times 10^3 \text{ acre ft}$$

1.18 Because Earth's rotation is gradually slowing, the length of each day increases: The day at the end of the 1.0 century is 1.0 ms longer than the day at the start of the century. In 20 centuries, what is the total of the daily increases in time (that is, the sum of the gain on the first day, the gain on the second day)



We did this one in class. We can plot the excess time each day as the centuries pass. The accumulated extra time is the area under the curve. We can compute this by computing the area of the triangle, remembering that the base length needs to be expressed in days, since the vertical is excess time per day.

$$t = \frac{1}{2} \cdot (20 \text{ centuries} \cdot \frac{100 \text{ yr}}{1 \text{ century}} \cdot \frac{365.25 \text{ days}}{\text{yr}}) \cdot \frac{0.020 \text{ s}}{\text{day}} = 7305 \text{ s}$$

1.20. Gold, which has a mass of 19.32 g for each cubic centimeter of volume, is the most ductile metal and can be pressed into a thin leaf or drawn out into a long fiber. (a) If 1.000 oz of gold, with a mass of 27.63 g is pressed into a leaf of 1.000 microns thickness, what is the area of the

leaf? (b) If, instead, the gold is drawn out into a cylindrical fiber of radius of 2.5 microns, what is the length of the fiber.

In this problem, the volume of the gold remains constant. It simply gets “reshaped” into different shapes. We compute the volume first...

$$V = 27.63g \cdot \frac{1cm^3}{19.32g} = 1.43cm^3$$

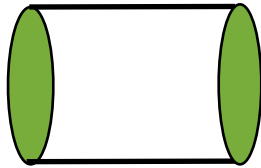
(a) In the case of a thin sheet of leaf, the volume is



$$V = Area \cdot thickness$$

$$Area = \frac{V}{thickness} = \frac{1.43cm^3}{1 \times 10^{-4}cm} = 1.43 \times 10^4 cm^2$$

(b) In the case of a cylinder, the volume is



$$V = \pi r^2 l$$

$$l = \frac{V}{\pi r^2} = \frac{1.43cm^3}{\pi (2.5 \times 10^{-4}cm)^2} = 7.28 \times 10^6 cm$$

1.24 One cubic centimeter of a typical cumulus cloud contains 50 to 500 water drops, which have a typical radius of 10 microns. For that range, give the lower value and the higher values, respectively, for the following. (a) How many cubic meters of water are in a cylindrical cumulus cloud of height 3.0 km and radius 1.0 km. (b) How many 1-liter pop bottles would that water fill? (c) Water has a mass of 1000 kg per cubic meter of volume. How much mass does the water in the cloud have?

We will calculate the lower number first. The higher values will be 10 times larger since the number of drops is 10 times higher.

a) We are told that the cloud is a cylinder. We begin by calculating the volume of the cloud in cubic cm. This will require us to convert the cloud dimensions to cm.

$$r_{cloud} = 1 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 1 \times 10^5 \text{ cm}$$

$$h_{cloud} = 3 \text{ km} \cdot \frac{1000 \text{ m}}{1 \text{ km}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} = 3 \times 10^5 \text{ cm}$$

$$V_{cloud} = \pi r^2 h = \pi \cdot (1 \times 10^5 \text{ cm})^2 \cdot 3 \times 10^5 \text{ cm} = 9.42 \times 10^{15} \text{ cm}^3$$

$$V_{water \text{ in cloud}} = V_{cloud} \cdot \frac{\# \text{ drops}}{\text{cm}^3 \text{ of cloud}} \cdot V_{drop}$$

$$\begin{aligned} V_{water \text{ in cloud}} &= 9.42 \times 10^{15} \text{ cm}^3 \cdot \frac{50 \text{ drops}}{\text{cm}^3} \cdot \frac{4}{3} \pi (10 \times 10^{-6} \text{ m})^3 \\ &= 1972.9 \text{ m}^3 \end{aligned}$$

The upper limit would be 19729 m^3

b. We can find the number of 1 L pop-bottles by converting the volume of water to L. The number of L will be the number of bottles.

$$1 \text{ m}^3 = 1000 \text{ L}$$

$$V_{water \text{ in cloud}} = 1972.9 \text{ m}^3 \cdot \frac{1000 \text{ L}}{1 \text{ m}^3} = 1.9729 \times 10^6 \text{ L}$$

The upper limit is $1.9729 \times 10^7 \text{ L}$.

c We can now compute the mass of water in the cloud.

$$m = V_{water \text{ in cloud}} \cdot \rho_{water} = 1972.9 \text{ m}^3 \cdot \frac{1000 \text{ kg}}{1 \text{ m}^3} = 1.9729 \times 10^6 \text{ kg}$$

The upper limit is $1.9729 \times 10^7 \text{ kg}$.

1.28 Grains of fine California beach sand are approximately spheres with an average radius of $50 \mu\text{m}$; They are made of silicon dioxide, 1 m^3 of which has a mass of 2600 kg. What mass of sand grains would have a total surface area equal to the surface area of a cube 1 m on edge?

We begin by computing the surface area of one grain and the total area we are looking for (which is the surface area of the cube). We also simply record the density of silicon.

$$a_{sand} = 4\pi r^2 = 4\pi \cdot (50 \times 10^{-6} m)^2 = 3.14 \times 10^{-8} m^2$$

$$a_{cube} = 6l^2 = 6 \cdot (1m)^2 = 6m^2$$

$$\rho(\text{density}) = \frac{2600kg}{1m^3} = 2600 \frac{kg}{m^3}$$

Now we compute the number of grains of sand. The total area should be the the number of grains times the area per grain.

$$a_{cube} = (\# \text{ grains}) \cdot a_{sand}$$

$$\# \text{ grains} = \frac{a_{cube}}{a_{sand}} = \frac{6m^2}{3.14 \times 10^{-8} m^2} = 1.91 \times 10^8$$

Knowing the number of grains, we can use the density to compute the mass.

$$\begin{aligned} m &= (\# \text{ grains} \cdot \text{Volume}_{\text{grain}}) \cdot \rho \\ &= 1.91 \times 10^8 \cdot \frac{4}{3} \pi (50 \times 10^{-6} m)^3 \cdot 2600 \frac{kg}{m^3} \\ &= 2.6 \times 10^{-1} kg \end{aligned}$$

1.36 Two types of barrel units were in use in the 1920's in the United States. the apple barrel had a legally set volume of 7056 cubic inches; the cranberry barrel 5826 cubic inches. If a merchant sells 20 cranberry barrels of goods to a customer who thinks he is receiving apple barrels, what is the discrepancy in the shipment volume in liters.

The difference in volume of one barrel is:

$$\Delta V = 7056 - 5826 = 1230 \text{ in}^3$$

For 20 barrels,

$$\begin{aligned} \Delta V_{Total} &= 20 \cdot 1230 \text{ in}^3 \\ &= 24,600 \text{ in}^3 \end{aligned}$$

We now convert to liters

$$\begin{aligned} \Delta V_{Total} &= 24,600 \text{ in}^3 \cdot \frac{1.639 \times 10^{-2} L}{1 \text{ in}^3} \\ &= 403.19 L \end{aligned}$$

1.39 A cord is a volume of cut wood equal to a stack 8 ft long, 4 ft wide, and 4 ft high. How many cords are in $1 m^3$?

$$1 \text{ cord} = 4 \text{ ft} \times 4 \text{ ft} \times 8 \text{ ft} = 128 \text{ ft}^3$$

$$V = 1 m^3 \cdot \left(\frac{1 \text{ ft}}{0.3048} \right)^3 \cdot \frac{1 \text{ cord}}{128 \text{ ft}^3} = 2.759 \times 10^{-1} \text{ cord}$$

1.45 An astronomical unit (AU) is the average distance of Earth from the Sun approximately $1.5 \times 10^8 \text{ km}$. The speed of light is about $3.0 \times 10^8 \text{ m/s}$. Express the speed of light in Astronomical Units per minute

$$c = \frac{3.0 \times 10^8 \text{ m}}{\text{s}} \cdot \frac{1 \text{ km}}{1000 \text{ m}} \cdot \frac{1 \text{ AU}}{1.5 \times 10^8 \text{ km}} \cdot \frac{60 \text{ s}}{1 \text{ min}} = 0.12 \frac{\text{AU}}{\text{min}}$$

1.46 What mass of water fell on the town in problem 9

Let's calculate the volume of water in MKS units and then find mass.

$$d = 2 \text{ in} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{1 \text{ m}}{100 \text{ cm}} = 5.08 \times 10^{-2} \text{ m}$$

$$A = 26 \text{ km}^2 \cdot \left(\frac{1000 \text{ m}}{1 \text{ km}} \right)^2 = 2.6 \times 10^7 \text{ m}^2$$

$$V = A \cdot d = 2.6 \times 10^7 \text{ m}^2 \cdot 5.08 \times 10^{-2} \text{ m} = 1.32 \times 10^6 \text{ m}^3$$

$$m = V \cdot \rho = 1.32 \times 10^6 \text{ m}^3 \cdot \frac{1000 \text{ kg}}{1 \text{ m}^3} = 1.32 \times 10^9 \text{ kg}$$

1.51 (a) A unit of time sometimes used in microscopic physics is the shake. One shake equals 10^{-8} s . Are there more shakes in a second than there are seconds in a year? (b) Humans have existed for about 10^6 years whereas the universe is about 10^{10} years old. If the age of the universe is taken to be 1 “universe day”, where a universe day consists of “universe seconds” as a normal day consists of normal seconds, how many “universe seconds” have humans existed?

(a) Compute the number of shakes in a second and the number of seconds in a year.

$$\# \text{ s in a shake} = \frac{1 \text{ s}}{10^{-8} \text{ s/shake}} = 10^8$$

$$\# \text{ s in a year} = 1 \text{ yr} \cdot \frac{365.25 \text{ days}}{1 \text{ yr}} \cdot \frac{24 \text{ hrs}}{1 \text{ day}} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} = 3.156 \times 10^7$$

There are more shakes in a second than seconds in a year.

(b) We set up a ratio to do this problem

$$\begin{aligned} \frac{x}{1 \text{ universe day}} &= \frac{10^6 \text{ yrs}(\text{human existence})}{10^{10} \text{ yrs}(\text{universe})} \\ x &= 10^{-4} \text{ universe day} \\ &= 10^{-4} \text{ universe day} \cdot \frac{24 \text{ universe hours}}{1 \text{ universe day}} \cdot \frac{3600 \text{ universe sec}}{1 \text{ universe hour}} \\ &= 8.64 \text{ universe sec} \end{aligned}$$

Note: I take some issue with the author's claim that humans have been around for 10^6 years. This is dependent on our definition of human, but a better estimated is probably $1-5 \times 10^5$ years.

1.57 An Astronomical Unit (AU) is equal to the average distance from the Earth to the Sun, about $92.9 \times 10^6 \text{ mi}$. A parsec (pc) is the distance at which a length of 1 AU would subtend an angle of exactly 1 second of arc (Fig. 1-9) A light-year (ly) is the distance that light, traveling through a vacuum with a speed of 186,000 mi/s, would cover in 1.0 year. Express the Earth-Sun distance in (a) parsecs and (b) light years.

We begin by defining a parsec in terms of meters. We do this by recognizing that the relation between a parsec and an AU is given by the relationship between an arc length and a radius

$$\begin{aligned} \text{arclength} &= r\theta \\ \theta &= 1s \cdot \frac{1 \text{ min}}{60 \text{ sec}} \cdot \frac{1 \text{ deg}}{60 \text{ min}} \cdot \frac{2\pi \text{ radians}}{360 \text{ deg}} = 4.85 \times 10^{-6} \text{ rad} \\ \text{arclength} &= 1 \text{ AU} \cdot \frac{92.9 \times 10^6 \text{ mi}}{1 \text{ AU}} \cdot \frac{1600 \text{ m}}{1 \text{ mi}} = 1.49 \times 10^{11} \text{ m} \\ r &= \frac{\text{arclength}}{\theta} = \frac{1.49 \times 10^{11} \text{ m}}{4.85 \times 10^{-6} \text{ rad}} = 3.06 \times 10^{16} \text{ m} \\ 1 \text{ pc} &= 3.06 \times 10^{16} \text{ m} \end{aligned}$$

Now we can write the earth-sun distance in parsecs

$$d_{es} = 92.9 \times 10^6 \text{ mi} \cdot \frac{1600 \text{ m}}{1 \text{ mi}} \cdot \frac{1 \text{ pc}}{3.06 \times 10^{16} \text{ m}} = 4.86 \times 10^{-6} \text{ pc}$$

To compute the distance in light years, we need to find how many miles are in one light year. The distance that light travels in one year is

$$1 \text{ ly} = \frac{186,000 \text{ mi}}{s} \cdot \left(1 \text{ yr} \cdot \frac{365.25 \text{ days}}{1 \text{ yr}} \cdot \frac{24 \text{ hrs}}{1 \text{ day}} \cdot \frac{3600 \text{ s}}{1 \text{ hr}} \right) = 5.87 \times 10^{12} \text{ mi}$$

Now we find the distance in light-years

$$d_{es} = 92.9 \times 10^6 \text{ mi} \cdot \frac{1 \text{ ly}}{5.87 \times 10^{12}} = 1.58 \times 10^{-5} \text{ ly}$$