Chapter 1 Problems

1.3 The micrometer is often called the micron. (a) How man 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

$$d = 1.0km \cdot \frac{1000m}{1\,km} \cdot \frac{1micron}{1\times10^{-6}m} = 1\times10^{9} microns$$

Now calculate a distance of 1 micron in cm.

$$d = 1micron \cdot \frac{1\times10^{-6}m}{1micron} \cdot \frac{100\,cm}{1m} = 1\times10^{-4}\,cm$$

Finally we compute a distance of 1 yard in microns.

$$d = 1\,yd \cdot \frac{3\,ft}{1\,yd} \cdot \frac{0.3048\,m}{1\,ft} \cdot \frac{1micron}{1\times10^{-6}m} = 9.144\times10^{5} microns$$

1.5 The Earth is approximately a sphere of radius 6.37 x 10^6 m. (a) What is 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.

$$r = 6.37\times10^{6}\,m \cdot \frac{1km}{1000m} = 6.37\times10^{3}\,km$$

(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.

$$c = 2\pi\, r = 2\pi \cdot 6.37\times10^{3}\,km = 4.002\times10^{4}\,km$$

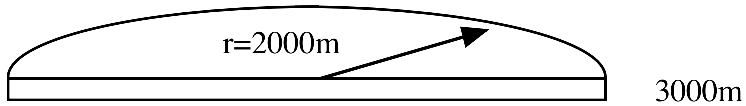
(b) The surface area of a sphere is:

$$a = 4\pi r^{2} = 4\pi \cdot (6.37\times10^{3}\,km)^{2} = 5.099\times10^{8}\,km^{2}$$

(c) The volume of a sphere is:

$$v = \frac{4}{3}\pi\, r^{3} = \frac{4}{3}\pi \cdot (6.37\times10^{3}\,km)^{3} = 1.083\times10^{12}\,km^{3}$$

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) *(Corrected)*



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

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

1.9 Hydraulic engineers often use, as a unit of volume of water, the acre-foot, defined a 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 km^2. What volume of water in acre-feet, fell on the town?

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

$$
\begin{aligned}
d &= 2.0in \cdot \frac{1ft}{12in} = 0.1667 ft \\
a &= 26km^2 \cdot (\frac{1000m}{1km})^2 \cdot \frac{2.471acres}{10^4 m^2} = 6.4245 \times 10^3 acres \\
Volume &= a \cdot d = 6.4245 \times 10^3 acres \cdot 0.1667 ft \\
&= 1.071 \times 10^3 acre\ ft
\end{aligned}
$$

1.11 A fortnight is a charming English measure of time equal to 2.0 weeks (the word is a contraction of “fourteen nights”). That is a nice amount of time in pleasant company but perhaps a painful string of microseconds in unpleasant company. How many microseconds are in a fortnight.

$$
\#\ micros = 1\ \ fortnight \cdot \frac{14 days}{1\ fortnight} \cdot \frac{24h}{1d} \cdot \frac{3600s}{1h} \cdot \frac{1\mu s}{10^{-6} s} = 1.2096 \times 10^{12}
$$

1.14 Until 1883, eery city and town in the United states kept its own local time. Today, travelers reset their watches only when the time change equals 1 hour (or more). How far, on average, must you travel in degrees of longitude until your watch must be reset by 1 h? (Hint: Earth rotates 360 degrees in 24 h.)

$$
\begin{aligned}
\frac{360°}{24h} &= \frac{x}{1h} \\
x &= \frac{360}{24}° = 15°
\end{aligned}
$$

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)

See class notes.

1.21 Earth has a mass of $5.98 \times 10^{24} kg$. The average mass of the atoms that make up the earth is 40 u. How many atoms are there in the earth.

To proceed, we need to find the conversion of atomic mass units (u) to kilograms.

$$1\ u = 1.661 \times 10^{-27}\ kg$$

We can now proceed

$$m_{Earth} = \#\ atoms \cdot avg.\ mass\ of\ each\ atom$$

$$\begin{aligned}\#\ atoms &= \frac{m_{Earth}}{avg.\ mass\ of\ each\ atom} \\ &= \frac{5.98 \times 10^{24}\ kg}{40u \cdot \dfrac{1.661 \times 10^{-27}\ kg}{1u}} \\ &= 9 \times 10^{49}\end{aligned}$$

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. (as) 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.

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

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

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

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

$$V_{water\,in\,cloud} = 9.42 \times 10^{15}\,cm^3 \cdot \frac{50 drops}{cm^3} \cdot \frac{4}{3}\pi (10 \times 10^{-6}\,m)^3$$

$$= 1972.9\,m^3$$

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.

$$1\,m^3 = 1000\,L$$

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

The upper limit is $1.9729 \times 10^7\,L$.

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

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

The upper limit is $1.9729 \times 10^7\,kg$.

1.33 Grains of fine California beach sand are approximately spheres with an average radius of 50 mm; 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 1m on edge?

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

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

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

Now we compute the number of grains of sand

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

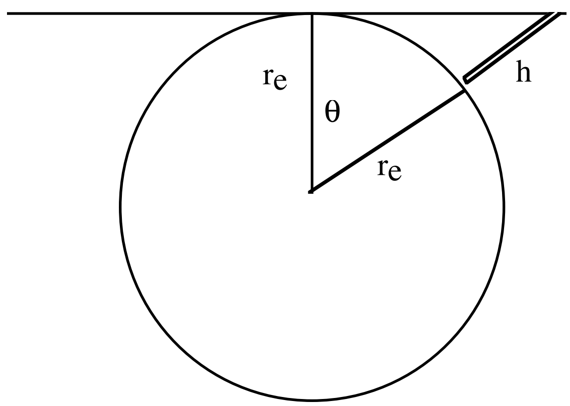
$$\#\,grains = \frac{a_{cube}}{a_{sand}} = \frac{6m^2}{3.14 \times 10^{-8}\,m^2} = 1.91 \times 10^8$$

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

$$
\begin{aligned}
m &= (\#\, grains \cdot Volume_{grain}) \cdot \rho \\
&= 1.91\times10^{8} \cdot \frac{4}{3}\pi(50\times10^{-6}m)^{3} \cdot 2600\frac{kg}{m^{3}} \\
&= 2.6\times10^{-1}kg
\end{aligned}
$$

1.36 Suppose that, while lying on the beach near the equator watching the Sun set over a calm ocean, you start a stopwatch just as the top of the Sun disappears. You then stand, elevating your eyes by a height h=1.7m, and stop the watch when the top of the Sun again disappears If the elapsed time is 11.1s, what is the radius of the earth.

Getting the picture is critical for doing this problem. We are trying to find h. To proceed, we find the angle that the earth turns through in 11.1 s.



This is the angle in the picture.

$$
\begin{aligned}
&\frac{\theta}{11.1s} = \frac{360°}{24hrs \cdot 60\min/hr \cdot 60\sec/\min} \\
&\theta = 4.625\times10^{-2\circ}
\end{aligned}
$$

We now use some geometry to find h

$$
\begin{aligned}
&\cos\theta = \frac{r_e}{r_e + h} \\
&(r_e + h)\cos\theta = r_e \\
&h\cos\theta = r_e - r_e\cos\theta \\
&r_e = \frac{h\cos\theta}{1-\cos\theta} = \frac{1.7m\cdot\cos(4.625\times10^{-2})}{1-\cos(4.625\times10^{-2})} = 5.22\times10^{6}m
\end{aligned}
$$

This isn't a great value, but not bad for lying on the beach.

1.40 One molecule of water contains two atoms of hydrogen and one atom of oxygen. A hydrogen atom has a mass of 1.0 u and an atom oxygen has a mass of 16 u, approximately. (a)What is the mass in kilograms of one molecule of water. (b) How many molecules of water in the worlds oceans which have an estimated total mass of $1.4 \times 10^{21} kg$.

$$1\ u = 1.661 \times 10^{-27} kg$$

a) Mass of water molecule

$$\begin{aligned} m_{water\ molecule} &= 2 \cdot m_H + 1 \cdot m_O = 2 \cdot 1u + 1 \cdot 16u = 18u \\ &= 18u \cdot \frac{1.661 \times 10^{-27} kg}{1u} \\ &= 2.9898 \times 10^{-26} kg \end{aligned}$$

b) We can now calculate the number of molecules.

$$m_{ocean} = \#\,molecules \cdot \frac{mass}{molecule}$$

$$\#\,molecules = \frac{m_{ocean}}{\frac{mass}{molecule}} = \frac{1.4 \times 10^{21} kg}{2.9898 \times 10^{-26}} = 4.683 \times 10^{46}$$

1.48 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.

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

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

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

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

1.54 During heavy rain, a section of a mountainside measuring 2.5 km horizontally, 0.8 km up along the slope and 2.0 m deep slips into a valley in a mud slide. Assume that the mud ends up uniformly disturbed over a surface area of the valley measuring 0.4 km x 0.40 km and that the mass of a cubic meter of mud is 1900 kg. What is the mass of the mud sitting above a 4.0 sq m area of the valley floor.

We begin by computing the total volume of mud.

$$V = 2500m \times 800m \times 2m = 4{,}000{,}000m^3$$

Now we compute the depth of the mud in the valley. The volume remains constant.

$$V = 400m \times 400m \times d$$
$$d = \frac{V}{400m \times 400m} = 25m$$

Now that we know the depth, we can compute the volume of mud sitting above 4 sq. m.

$$V' = 4m^2 \cdot 25m = 100m^3$$

And the mass

$$m = \rho V' = \frac{1900\,kg}{m^3} \cdot 100m^3 = 190{,}000\,kg$$

1.58 (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.

$$\#\,s\ in\ a\ shake = \frac{1s}{10^{-8}s/shake} = 10^8$$
$$\#\,s\ in\ a\ year = 1yr \cdot \frac{365.25days}{1yr} \cdot \frac{24hrs}{1day} \cdot \frac{3600s}{1hr} = 3.156 \times 10^7$$

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

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

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