Chapter 1: MEASUREMENTS

- Physical Quantities:

  1. Base Quantities $\begin{Bmatrix} Time \\ Mass \\ Length \end{Bmatrix}$

  2. Derived Quantities are defined in terms of the base quantities and their standards and units.

Force = mass x acceleration

$$1\ N = 1\ Kg\ \frac{m}{s^2}$$

- The International System of Units (SI)

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

Prefixes for SI unit:

$$1\ m = 100\ cm = 10^2\ cm \rightarrow\rightarrow 1\ cm = \ 10^{-2}\ m$$

Factor	Prefix[a]	Symbol
10^{24}	yotta-	Y
10^{21}	zetta-	Z
10^{18}	exa-	E
10^{15}	peta-	P
10^{12}	tera-	T
$\mathbf{10^{9}}$	**giga-**	**G**
$\mathbf{10^{6}}$	**mega-**	**M**
$\mathbf{10^{3}}$	**kilo-**	**k**
10^{2}	hecto-	h
10^{1}	deka-	da
10^{-1}	deci-	d
$\mathbf{10^{-2}}$	**centi-**	**c**
$\mathbf{10^{-3}}$	**milli-**	**m**
$\mathbf{10^{-6}}$	**micro-**	$\boldsymbol{\mu}$
$\mathbf{10^{-9}}$	**nano-**	**n**
$\mathbf{10^{-12}}$	**pico-**	**p**
10^{-15}	femto-	f
10^{-18}	atto-	a
10^{-21}	zepto-	z
10^{-24}	yocto-	y

- Conversion of units(**Changing Units**):

By using chain-link Conversions in which the original data are multiplied successively by conversion factors written as unity and the units are manipulated like algebraic quantities until only the desired units remain.

A **conversion factor** is a ratio of units that is equal to unity.

$$1\ m = 100\ cm = 10^2\ cm \rightarrow\rightarrow \frac{1\ m}{10^2\ cm} = \frac{10^2\ cm}{1\ m} = 1$$

$$0.5\ \frac{Km}{min} = ?\ \frac{m}{s}$$

$$0.5\ \frac{Km}{min} = 0.5\ \frac{Km}{min}\left(\frac{1000\ m}{1\ Km}\right)\left(\frac{1\ min}{60\ s}\right) = 8.33\ \frac{m}{s}$$

- Estimation: التقدير

1-3) The micrometer (1 μm) is often called the *micron*. (a) How many microns make up 1.0 km? (b) What fraction of a centimeter equals 1.0 μm? (c) How many microns are in 1.0 yd?

(a) $1 \text{ Km} = 1 \times 10^3 \text{ m}$ and $1\text{m} = 10^6 \text{ µm}$,

$$1 \text{ Km} = 10^3 \text{ m} = (10^3\text{m})\left(\frac{10^6 \text{ µm}}{1 \text{ m}}\right) = 10^9 \mu m$$

$$1.0 \text{ Km} = 1.0 \times 10^9 \mu m$$

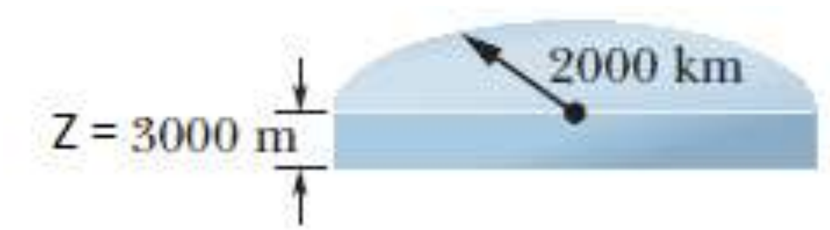
(b)$1\ \mu m = 10^{-6}\text{m} = (10^{-6}\text{m})\left(\frac{10^2 \text{ cm}}{1 \text{ m}}\right) = 10^{-4} \text{ cm}$

$$1.0 \text{ µm} = 1.0 \times 10^{-4} cm$$

(C) $1 \text{ yd} = (3\text{ft})\left(\frac{0.30448 \text{ m}}{1 \text{ ft}}\right) = 0.9144\ m$

$$1.0 \text{ yd} = (0.91 \text{ m})\left(\frac{10^6 \text{ µm}}{1 \text{ m}}\right) = 9.1 \times 10^5 \mu m$$

1-9) Antarctica is roughly semicircular, with a radius of 2000 km. The average thickness of its ice cover is 3000 m. How many cubic centimeters of ice does Antarctica contain? (Ignore the curvature of Earth.)



The volume of ice is given by the product of the semicircular surface area and the thickness.

The area of the semicircle: $A = \frac{\pi\, r^2}{2}$ =; r is the radius.

The volume of the ANTARTICA: $V = \frac{\pi\, r^2}{2}\, Z$

$$r = 2000\, Km = 2000\, Km \left(\frac{10^3 m}{1\, Km}\right)\left(\frac{10^2 cm}{1\, m}\right) = 2000 \times 10^5\, cm = 2 \times 10^8\, cm$$

$$z = 3000\, m = 3000\, m \left(\frac{10^2 cm}{1\, m}\right) = 3 \times 10^5\, cm$$

$$V = \frac{\pi\, r^2}{2}\, Z = \frac{\pi}{2}\,(2 \times 10^8\, cm)^2\, 3 \times 10^5\, cm = 1.9 \times 10^{22} cm^3$$

ANTARTICA contains $1.9 \times 10^{22} cm^3$ of ice

1-12) The fastest growing plant on record is a *Hesperoyucca whipplei* that grew 3.7 m in 14 days. What was its growth rate in micrometers per second?

$$\frac{3.7\ m}{14\ day} = \frac{3.7\ m}{14\ day}\left(\frac{10^6\ \mu m}{1\ m}\right)\left(\frac{1\ day}{24\ hour}\right)\left(\frac{1\ hour}{60\ minute}\right)\left(\frac{1\ minute}{60\ second}\right) = \frac{3.1\ \mu m}{second}$$

Growth Rate = 3.1 $\mu m/s$

1-21) Earth has a mass of 5.98×10^{24} kg. The average mass of the atoms that make up Earth is 40 u. How many atoms are there in Earth?

The number of atoms in EARTH (N):

$N = \frac{M_E}{m}$; M_E is the mass of Earth and m is the average mass of an atom.

$$M_E = 5.98 \times 10^{24}\ \text{Kg} = 5.98 \times 10^{24}\ \text{Kg} \left(\frac{1\ \text{u}}{1.661 \times 10^{-27}\ \text{Kg}}\right) = 3.6 \times 10^{51}\ \text{u}$$

$$N = \frac{M_E}{m} = \frac{3.6 \times 10^{51}\ \text{u}}{40\ \text{u}} = 9.0 \times 10^{49}$$

1-28) A mole of atoms is 6.02 x10^{23} atoms. To the nearest order of magnitude, how many moles of atoms are in a large domestic cat? The masses of a hydrogen atom, an oxygen atom, and a carbon atom are 1.0 u, 16 u, and 12 u, respectively. (*Hint:* Cats are sometimes known to kill a mole.)

By ESTIMATION;

Large domestic cat mass = 8 Kg $= 8\ Kg\left(\frac{1\text{ u}}{1.661\times10^{-27}\text{ Kg}}\right) = 4.82\ \times 10^{+27} u$

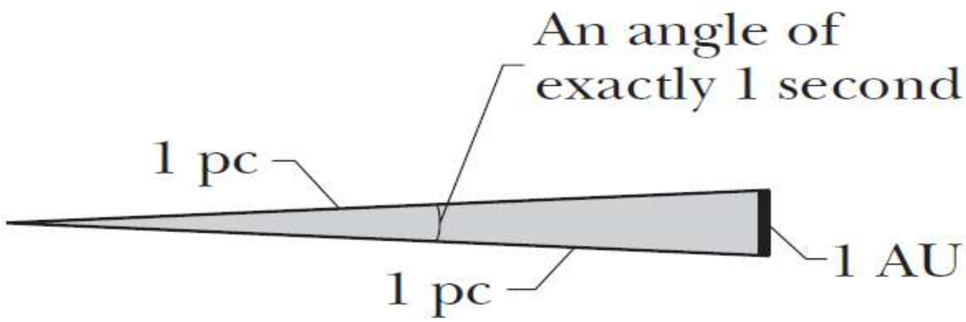
The average mass of atom in large domestic cat ≅ 10 u

Atoms in Large domestic cat = $\left(\frac{4.82\times10^{27} u}{10\text{ u}}\right) = 4.82\times10^{26}$ atoms

$$4.82\times10^{26}\ atoms = 4.82\times10^{26}\ atoms\left(\frac{1\ mole}{6.02\ \times10^{23} atom}\right) = 800.7\ mole$$

So, to the nearest order of magnitude, we would say a large domestic cat contains 1000 moles of atoms. (10^3 *moles of atoms*)

1-53) An *astronomical unit* (AU) is equal to the average distance from Earth to the Sun, about 92.9 x10^6 mi. A *parsec* (pc) is the distance at which a length of 1 AU would subtend an angle of exactly 1 second of arc. 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.



$\theta_{radians} = \frac{s}{R}$; s is the arc length and R is the radius

1AU = 92.9 x10^6 mi

(a) $1\ arcsec = \ 1\,\text{arcsec}\left(\frac{1\ arcmin}{60\ arcsec}\right)\left(\frac{1^{\circ}}{60\ arcmin}\right)\left(\frac{\pi}{180^{\circ}}\right) = 4.85\ \times 10^{-6}\ rad$

$$1\ AU = 1\ pc\ \times\ 4.85\ \times 10^{-6}\ rad = 4.9\ \times 10^{-6}\ pc$$

(b)$1\ ly = 186000\ \frac{mi}{s}\ (1\ year)\left(\frac{365\ day}{1\ year}\right)\left(\frac{24\ hour}{1\ day}\right)\left(\frac{60\ minute}{1\ hour}\right)\left(\frac{60\ second}{1\ minute}\right)$

$= \ 5.87\ \times 10^{12}\ mi$

$$1\ AU\ = 92.9\ \times 10^{6}\, mi\ \left(\frac{1\ ly}{5.87 \times 10^{12}\ mi}\right) = 1.58 \times 10^{-5}\ \ ly$$

$$1\ AU = 4.9\ \ \times 10^{-6}\, pc = \ 1.6 \times 10^{-5}\ \ ly$$

$$1\ pc = 3.2\ ly$$

1-23) (a) Assuming that water has a density of exactly 1 g/cm^3, find the mass of one cubic meter of water in kilograms. (b) Suppose that it takes 10.0 h to drain a container of 5700 m^3 of water. What is the "mass flow rate," in kilograms per second, of water from the container?

$$1\,m = 10^2\,cm \rightarrow\rightarrow (1\,m)^3 = (10^2\,cm)^3 \rightarrow\rightarrow 1\,m^3 = 10^6\,cm^3$$

$$1\,kg = 10^3\,g$$

(a) $1\,\frac{g}{cm^3} = 1\,\frac{g}{cm^3}\left(\frac{10^6\,cm^3}{1\,m^3}\right)\left(\frac{1\,kg}{10^3\,g}\right) = 10^3\,\frac{kg}{m^3}$

$$\rho = \frac{M}{V} \rightarrow\rightarrow M = \rho\,V$$

$$M = \rho\,V = 10^3\,\frac{kg}{m^3} \times 1\,m^3 = 10^3\,kg$$

(b) The total mass of water in the container:

$$M = \rho\,V = 10^3\,\frac{kg}{m^3} \times 5700\,m^3 = 5.7 \times 10^6\,kg$$

The mass flow rate R:

$$R = \frac{M}{t} = \frac{5.7 \times 10^6\,kg}{10.0\,h} = \frac{5.7 \times 10^6\,kg}{10.0\,h}\left(\frac{1\,hour}{60\,minute}\right)\left(\frac{1\,minute}{60\,second}\right)$$
$$= 158.33\,kg/s$$

$$R = 158.33\,kg/s$$