CHAPTER 1

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TOPICS DISCUSSED

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1–5 UNITS, STANDARDS, AND THE SI SYSTEM

- Unit: Particular standard of measurement
- For any unit we use, such as the meter for distance or the second for time, we need to define a standard

- **<u>Length</u>**
  → The standard unit of length is meter (m) , it's defined now as: "The meter is the length of path traveled by light in vacuum during a time interval of a 1/299,792,458 of a second."
  → British units of length (inch, foot, mile) are now defined in terms of the meter. The inch (in.) is defined as exactly 2.54 centimeters (cm).

1–5 UNITS, STANDARDS, AND THE SI SYSTEM

- **Time**
  → The standard unit of time is the second (s).
  → The standard second is now defined more precisely in terms of the frequency of radiation emitted by cesium atoms when they pass between two particular states. [Specifically, one second is defined as the time required for 9,192,631,770 oscillations of this radiation.]
  → 60 s in one minute (min) and 60 minutes in one hour (h).

- **Mass**
  The standard unit of mass is the kilogram (kg). The standard mass is a particular platinum–iridium cylinder, kept at the International Bureau of Weights and Measures near Paris, France, whose mass is defined as exactly 1 kg.

1–5 UNITS, STANDARDS, AND THE SI SYSTEM

Systems of Units

When dealing with the laws and equations of physics it is very important to use a consistent set of units. Several systems of units have been in use over the years. Today the most important is the **Système International** (French for International System), which is abbreviated SI. In SI units, the standard of length is the meter, the standard for time is the second, and the standard for mass is the kilogram. This system used to be called the MKS (meter-kilogram-second) system.

A second metric system is the **cgs system**, in which the centimeter, gram, and second are the standard units of length, mass, and time, as abbreviated in the title. The **British engineering system** (although more used in the U.S. than Britain) has as its standards the foot for length, the pound for force, and the second for time.

We use SI units almost exclusively in this book.

1–5 UNITS, STANDARDS, AND THE SI SYSTEM

- Base vs. Derived Quantities
  → Physical quantities can be divided into two categories: base quantities and derived quantities
  → A **base quantity** must be defined in terms of a standard
  → All other quantities can be defined in terms of these seven base quantities, and hence are referred to as **derived quantities**. An example of a derived quantity is speed, which is defined as distance divided by the time it takes to travel that distance

TABLE 1–5 SI Base Quantities and Units

Quantity	Unit	Unit Abbreviation
Length	meter	m
Time	second	s
Mass	kilogram	kg
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

1–5 UNITS, STANDARDS, AND THE SI SYSTEM

- Unit Prefixes: In the metric system, the larger and smaller units are defined in multiples of 10 from the standard unit, and this makes calculation particularly easy (e.g. 1 μm (= 10^{-6}m) also called micron)

TABLE 1–4 Metric (SI) Prefixes

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro†	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

† μ is the Greek letter "mu."

1–6 CONVERTING UNITS

- conversion factor: A formula to convert between units
  (e.g. 1 in. = 2.54 cm)

Convert units

Length

1 = 0.9144

Yard | Meter

FORMULA for an approximate result, divide the length value by 1.0936133

Convert units

Length

1 = 3

Yard | Foot

FORMULA multiply the length value by 3

Convert units

Length

1 = 0.62137119

Kilometer | Mile

FORMULA for an approximate result, divide the length value by 1.609344

Convert units

Length

1 = 5280

Mile | Foot

FORMULA multiply the length value by 5280

EXAMPLE 1–3 **The 8000-m peaks.** There are only 14 peaks whose summits are over 8000 m above sea level. They are the tallest peaks in the world (Fig. 1–9 and Table 1–6) and are referred to as "eight-thousanders." What is the elevation, in feet, of an elevation of 8000 m?

APPROACH We need to convert meters to feet, and we can start with the conversion factor 1 in. = 2.54 cm, which is exact. That is, 1 in. = 2.5400 cm to any number of significant figures, because it is *defined* to be.

SOLUTION One foot is 12 in., so we can write

$$1\text{ ft} = (12\ \cancel{\text{in.}})\left(2.54\ \frac{\text{cm}}{\cancel{\text{in.}}}\right) = 30.48\text{ cm} = 0.3048\text{ m},$$

which is exact. Note how the units cancel (colored slashes). We can rewrite this equation to find the number of feet in 1 meter:

$$1\text{ m} = \frac{1\text{ ft}}{0.3048} = 3.28084\text{ ft}.$$

(We could carry the result to 6 significant figures because 0.3048 is exact, 0.304800....) We multiply this equation by 8000.0 (to have five significant figures):

$$8000.0\text{ m} = (8000.0\ \cancel{\text{m}})\left(3.28084\ \frac{\text{ft}}{\cancel{\text{m}}}\right) = 26{,}247\text{ ft}.$$

An elevation of 8000 m is 26,247 ft above sea level.

NOTE We could have done the conversion all in one line:

$$8000.0\text{ m} = (8000.0\ \cancel{\text{m}})\left(\frac{100\ \cancel{\text{cm}}}{1\ \cancel{\text{m}}}\right)\left(\frac{1\ \cancel{\text{in.}}}{2.54\ \cancel{\text{cm}}}\right)\left(\frac{1\text{ ft}}{12\ \cancel{\text{in.}}}\right) = 26{,}247\text{ ft}.$$

The key is to multiply conversion factors, each equal to one (= 1.0000), and to make sure which units cancel.

Metric Conversion

Linear Measure

1 centimeter	0.3937 inch
1 inch	2.54 centimeters
1 decimeter	3.937 in., 0.328 foot
1 foot	3.048 decimeters
1 meter	39.37 inches, 1.0936 yds.
1 yard	0.9144 meter
1 dekameter	1.9884 rods
1 rod	0.5029 dekameter
1 kilometer	0.62137 mile
1 mile	1.6094 kilometers

Square Measure

1 sq. centimeter	0.1550 sq. inches
1 sq. inch	6.452 sq. centimeters
1 sq. decimeter	0.1076 sq. foot
1 sq. foot	9.2903 sq. decimeters
1 sq. meter	1.196 yards
1 sq. yard	0.8361 sq. meter
1 hectare	2.471 acres
1 acre	0.4047 hectare
1 sq. kilometer	0.386 sq. mile

Measure of Volume

1 cu. centimeter	0.06 1 cu. inch
1 cu. Inch	16.39 cu. centimeters
1 cu. decimeter	0.0353 cu. foot
1 cu. foot	28.3 17 cu. decimeters
1 cu. yard	0.7646 cu. meters
1 cu. meter	0.2759 cord
1 cord	3.625 steres
1 liter	0.908 qt. dry 1.0567 qts. liq.
1 quart dry	1.101 liters
1 quart liquid	0.9463 liter
1 dekaliter	2.64l7 gals, 1.135 pks.
1 gallon	0.3785 dekaliter
1 peck	0.881 dekaliter
1 hectoliter	2.8378 bushels
1 bushel	0.3524 hectoliter

Weights

1 gram	0.03527 ounce
1 ounce	28.35 grams
1 kilogram	2.2046 pounds
1 pound	0.4536 kilogram

EXAMPLE 1–4 **Apartment area.** You have seen a nice apartment whose floor area is 880 square feet (ft^2). What is its area in square meters?

APPROACH We use the same conversion factor, 1 in. = 2.54 cm, but this time we have to use it twice.

SOLUTION Because 1 in. = 2.54 cm = 0.0254 m, then

$$1\ \text{ft}^2 = (12\ \text{in.})^2(0.0254\ \text{m/in.})^2 = 0.0929\ \text{m}^2.$$

So

$$880\ \text{ft}^2 = (880\ \text{ft}^2)(0.0929\ \text{m}^2/\text{ft}^2) \approx 82\ \text{m}^2.$$

NOTE As a rule of thumb, an area given in ft^2 is roughly 10 times the number of square meters (more precisely, about 10.8×).

How many cm^3 are in 1.0 m^3?

(a) 10. **(b)** 100. **(c)** 1000. **(d)** 10,000. **(e)** 100,000. **(f)** 1,000,000.

EXERCISE E Would a driver traveling at 15 m/s in a 35 mi/h zone be exceeding the speed limit? Why or why not?

EXAMPLE 1–5 **Speeds.** Where the posted speed limit is 55 miles per hour (mi/h or mph), what is this speed (*a*) in meters per second (m/s) and (*b*) in kilometers per hour (km/h)?

APPROACH We again use the conversion factor 1 in. = 2.54 cm, and we recall that there are 5280 ft in a mile and 12 inches in a foot; also, one hour contains (60 min/h) × (60 s/min) = 3600 s/h.

SOLUTION (*a*) We can write 1 mile as

$$1\ \text{mi} = (5280\ \cancel{\text{ft}})\left(12\ \frac{\cancel{\text{in.}}}{\cancel{\text{ft}}}\right)\left(2.54\ \frac{\cancel{\text{cm}}}{\cancel{\text{in.}}}\right)\left(\frac{1\ \text{m}}{100\ \cancel{\text{cm}}}\right)$$
$$= 1609\ \text{m}.$$

We also know that 1 hour contains 3600 s, so

$$55\ \frac{\text{mi}}{\text{h}} = \left(55\ \frac{\cancel{\text{mi}}}{\cancel{\text{h}}}\right)\left(1609\ \frac{\text{m}}{\cancel{\text{mi}}}\right)\left(\frac{1\ \cancel{\text{h}}}{3600\ \text{s}}\right)$$
$$= 25\ \frac{\text{m}}{\text{s}},$$

where we rounded off to two significant figures.

(*b*) Now we use 1 mi = 1609 m = 1.609 km; then

$$55\ \frac{\text{mi}}{\text{h}} = \left(55\ \frac{\cancel{\text{mi}}}{\text{h}}\right)\left(1.609\ \frac{\text{km}}{\cancel{\text{mi}}}\right)$$
$$= 88\ \frac{\text{km}}{\text{h}}.$$

NOTE Each conversion factor is equal to one. You can look up most conversion factors in the Table inside the front cover.

1–8 DIMENSIONS AND DIMENSIONAL ANALYSIS

- dimensions of a quantity: the type of base units or base quantities that make it up
  → for example, are always length squared, abbreviated $[L^2]$ using square brackets; the units can be square meters, square feet, and so on. Velocity, on the other hand, can be measured in units of km/h, m/s or mi/h, but the dimensions are always a length [L] divided by a time [T]
  → The formula for a quantity may be different in different cases, but the dimensions remain the same. For example, the area of a triangle of base b and height h is $A = \frac{1}{2}bh$ whereas the area of a circle of radius r is $A = \pi r^2$
  The formulas are different in the two cases, but the dimensions of area are always $[L^2]$
  → Dimensions can be used as a help in working out relationships, a procedure referred to as dimensional analysis. One useful technique is the use of dimensions to check if a relationship is incorrect (Note that we add or subtract quantities only if they have the same dimensions)

1–8 DIMENSIONS AND DIMENSIONAL ANALYSIS

For example, suppose you derived the equation $v = v_0 + \frac{1}{2}at^2$, where v is the speed of an object after a time t, v_0 is the object's initial speed, and the object undergoes an acceleration a. Let's do a dimensional check to see if this equation could be correct or is surely incorrect. Note that numerical factors, like the $\frac{1}{2}$ here, do not affect dimensional checks. We write a dimensional equation as follows, remembering that the dimensions of speed are $[L/T]$ and (as we shall see in Chapter 2) the dimensions of acceleration are $[L/T^2]$:

$$\left[\frac{L}{T}\right] \stackrel{?}{=} \left[\frac{L}{T}\right] + \left[\frac{L}{T^2}\right][T^2]$$

$$\stackrel{?}{=} \left[\frac{L}{T}\right] + [L].$$

1–8 DIMENSIONS AND DIMENSIONAL ANALYSIS

Dimensional analysis can also be used as a quick check on an equation you are not sure about. For example, consider a simple pendulum of length ℓ. Suppose that you can't remember whether the equation for the period T (the time to make one back-and-forth swing) is $T = 2\pi\sqrt{\ell/g}$ or $T = 2\pi\sqrt{g/\ell}$, where g is the acceleration due to gravity and, like all accelerations, has dimensions $[L/T^2]$. (Do not worry about these formulas—the correct one will be derived in Chapter 11; what we are concerned about here is a person's recalling whether it contains ℓ/g or g/ℓ.) A dimensional check shows that the former (ℓ/g) is correct:

$$[T] = \sqrt{\frac{[L]}{[L/T^2]}} = \sqrt{[T^2]} = [T],$$

whereas the latter (g/ℓ) is not:

$$[T] \neq \sqrt{\frac{[L/T^2]}{[L]}} = \sqrt{\frac{1}{[T^2]}} = \frac{1}{[T]}.$$

The constant 2π has no dimensions and so can't be checked using dimensions.

QUESTIONS

To convert from ft^2 to yd^2, you should

(a) multiply by 3.
(b) multiply by 1/3.
(c) multiply by 9.
(d) multiply by 1/9.
(e) multiply by 6.
(f) multiply by 1/6.

Answer: D

QUESTIONS

17. (II) A typical atom has a diameter of about 1.0×10^{-10} m. (*a*) What is this in inches? (*b*) Approximately how many atoms are along a 1.0-cm line, assuming they just touch?

17. (*a*) $1.0\times10^{-10}\ \text{m} = (1.0\times10^{-10}\ \text{m})(39.37\ \text{in}/1\ \text{m}) = \boxed{3.9\times10^{-9}\ \text{in}}$

(*b*) $(1.0\ \text{cm})\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right)\left(\dfrac{1\ \text{atom}}{1.0\times10^{-10}\ \text{m}}\right) = \boxed{1.0\times10^{8}\ \text{atoms}}$

21. (II) American football uses a field that is 100.0 yd long, whereas a soccer field is 100.0 m long. Which field is longer, and by how much (give yards, meters, and percent)?

21. Since the meter is longer than the yard, the soccer field is longer than the football field.

$$\ell_{\text{soccer}} - \ell_{\text{football}} = 100.0\text{ m} \times \frac{1.094\text{ yd}}{1\text{ m}} - 100.0\text{ yd} = \boxed{9.4\text{ yd}}$$

$$\ell_{\text{soccer}} - \ell_{\text{football}} = 100.0\text{ m} - 100.0\text{ yd} \times \frac{1\text{ m}}{1.094\text{ yd}} = \boxed{8.6\text{ m}}$$

Since the soccer field is 109.4 yd compared with the 100.0-yd football field, the soccer field is $\boxed{9.4\%}$ longer than the football field.

33. (III) I agree to hire you for 30 days. You can decide between two methods of payment: either (1) \$1000 a day, or (2) one penny on the first day, two pennies on the second day and continue to double your daily pay each day up to day 30. Use quick estimation to make your decision, and justify it.

34. (III) Many sailboats are docked at a marina 4.4 km away on the opposite side of a lake. You stare at one of the sailboats because, when you are lying flat at the water's edge, you can just see its deck but none of the side of the sailboat. You then go to that sailboat on the other side of the lake and measure that the deck is 1.5 m above the level of the water. Using Fig. 1–16, where h = 1.5 m, estimate the radius R of the Earth.

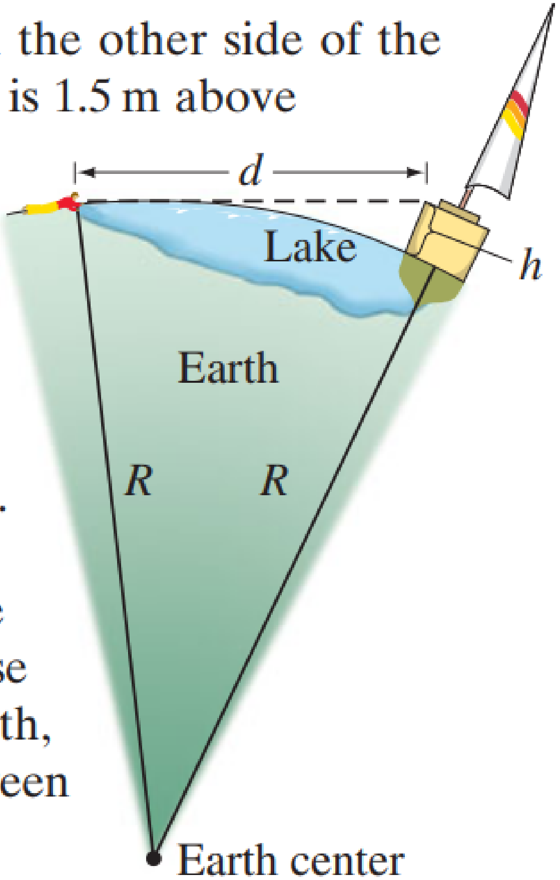


FIGURE 1–16 Problem 34. You see a sailboat across a lake (not to scale). R is the radius of the Earth. Because of the curvature of the Earth, the water "bulges out" between you and the boat.

33. At \$1,000 per day, you would earn \$30,000 in the 30 days. With the other pay method, you would get $\$0.01(2^{t-1})$ on the tth day. On the first day, you get $\$0.01(2^{1-1}) = \$0.01$. On the second day, you get $\$0.01(2^{2-1}) = \$0.02$. On the third day, you get $\$0.01(2^{3-1}) = \$0.04$. On the 30th day, you get $\$0.01(2^{30-1}) = \$5.4\times10^6$, which is over 5 million dollars. Get paid by the $\boxed{\text{second method}}$.

34. In the figure in the textbook, the distance d is perpendicular to the radius that is drawn approximately vertically. Thus there is a right triangle, with legs of d and R, and a hypotenuse of $R+h$. Since $h \ll R$, $h^2 \ll 2Rh$.

$$d^2 + R^2 = (R+h)^2 = R^2 + 2Rh + h^2 \rightarrow d^2 = 2Rh + h^2 \rightarrow d^2 \approx 2Rh \rightarrow R = \frac{d^2}{2h}$$

$$= \frac{(4400\text{ m})^2}{2(1.5\text{ m})} = \boxed{6.5\times10^6\text{ m}}$$

A better measurement gives $R = 6.38\times10^6$ m.

48. Hold a pencil in front of your eye at a position where its blunt end just blocks out the Moon (Fig. 1–19). Make appropriate measurements to estimate the diameter of the Moon, given that the Earth–Moon distance is 3.8×10^5 km.

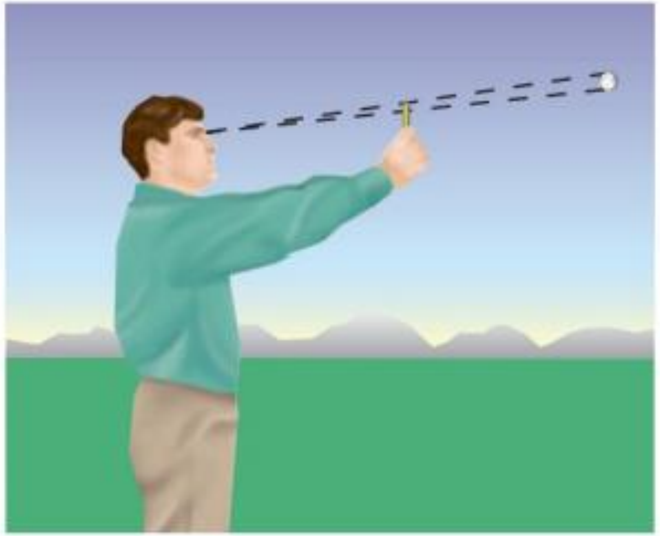
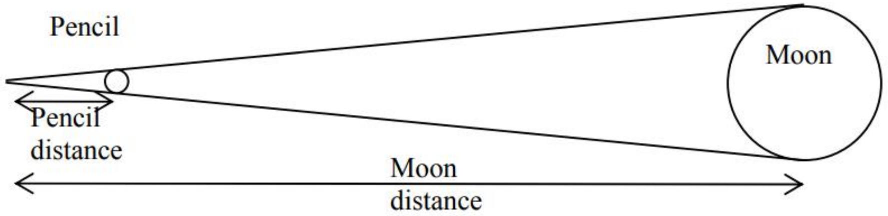


FIGURE 1–19
Problem 48. How big is the Moon?

48. A pencil has a diameter of about 0.7 cm. If held about 0.75 m from the eye, it can just block out the Moon. The ratio of pencil diameter to arm length is the same as the ratio of Moon diameter to Moon distance. From the diagram, we have the following ratios.



$$\frac{\text{Pencil diameter}}{\text{Pencil distance}} = \frac{\text{Moon diameter}}{\text{Moon distance}} \rightarrow$$

$$\text{Moon diameter} = \frac{\text{Pencil diameter}}{\text{Pencil distance}}(\text{Moon distance}) = \frac{7\times10^{-3}\ \text{m}}{0.75\ \text{m}}(3.8\times10^{5}\ \text{km}) \approx \boxed{3500\ \text{km}}$$

The actual value is 3480 km.