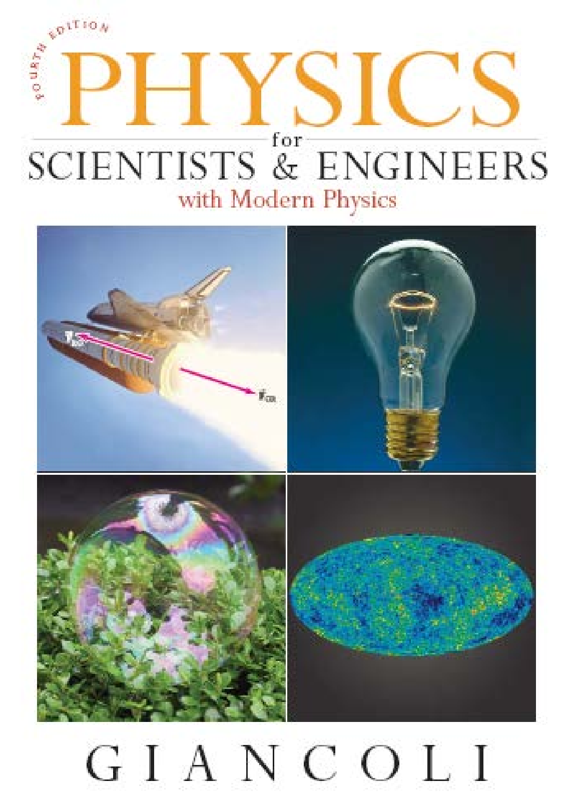


Lecture PowerPoints

Chapter 1

Physics for Scientists & Engineers, with Modern Physics, 4th edition

Giancoli

Chapter 1

Introduction, Measurement, Estimating

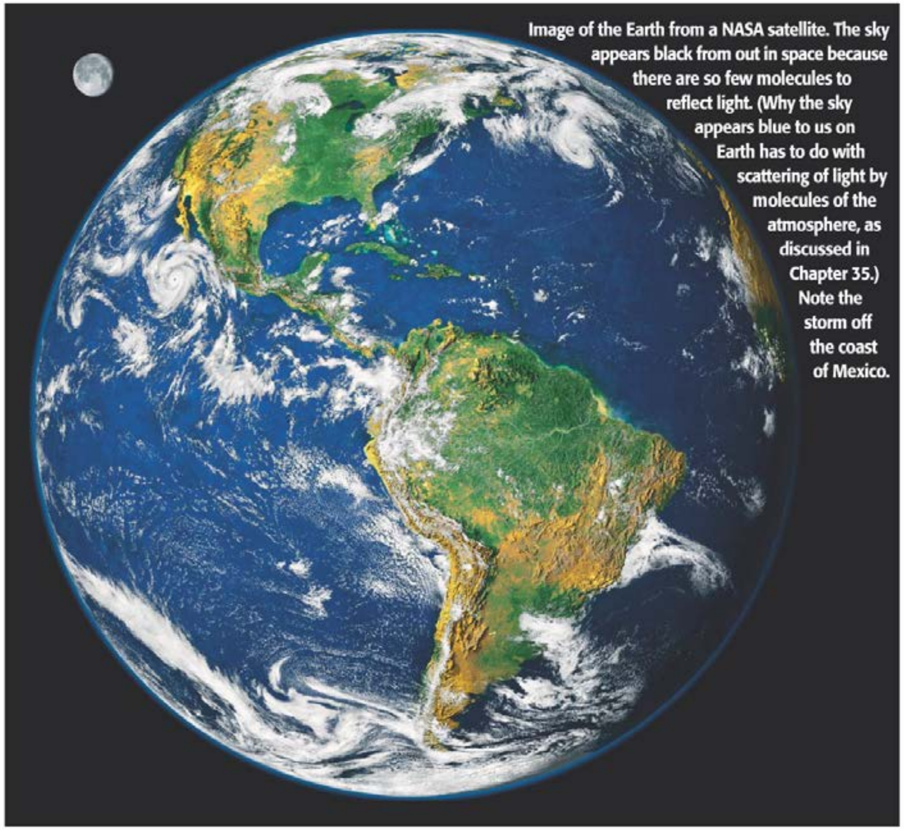


Image of the Earth from a NASA satellite. The sky appears black from out in space because there are so few molecules to reflect light. (Why the sky appears blue to us on Earth has to do with scattering of light by molecules of the atmosphere, as discussed in Chapter 35.) Note the storm off the coast of Mexico.

Units of Chapter 1

- The Nature of Science
- Models, Theories, and Laws
- Measurement and Uncertainty; Significant Figures
- Units, Standards, and the SI System
- Converting Units
- Order of Magnitude: Rapid Estimating
- Dimensions and Dimensional Analysis

1-1 The Nature of Science

Observation: important first step toward scientific **theory**; requires **imagination** to tell what is important

Theories: created to explain **observations**; will make **predictions**

Observations will tell if the **prediction** is accurate, and the cycle goes on.

No theory can be absolutely **verified**, although a theory can be proven false.

1-1 The Nature of Science

How does a **new theory** get accepted?

- **Predictions** agree better with data
- **Explains** a greater range of phenomena

Example: **Aristotle** believed that objects would return to a **state of rest** once put in motion.

Galileo realized that an object **put in motion** would **stay in motion** until some force stopped it.

1-1 The Nature of Science

The principles of physics are used in many practical applications, including construction. **Communication** between architects and engineers is essential if disaster is to be avoided.

1-2 Models, Theories, and Laws

Models are very useful during the process of understanding phenomena. A model creates **mental pictures**; care must be taken to understand the **limits** of the model and not take it too seriously.

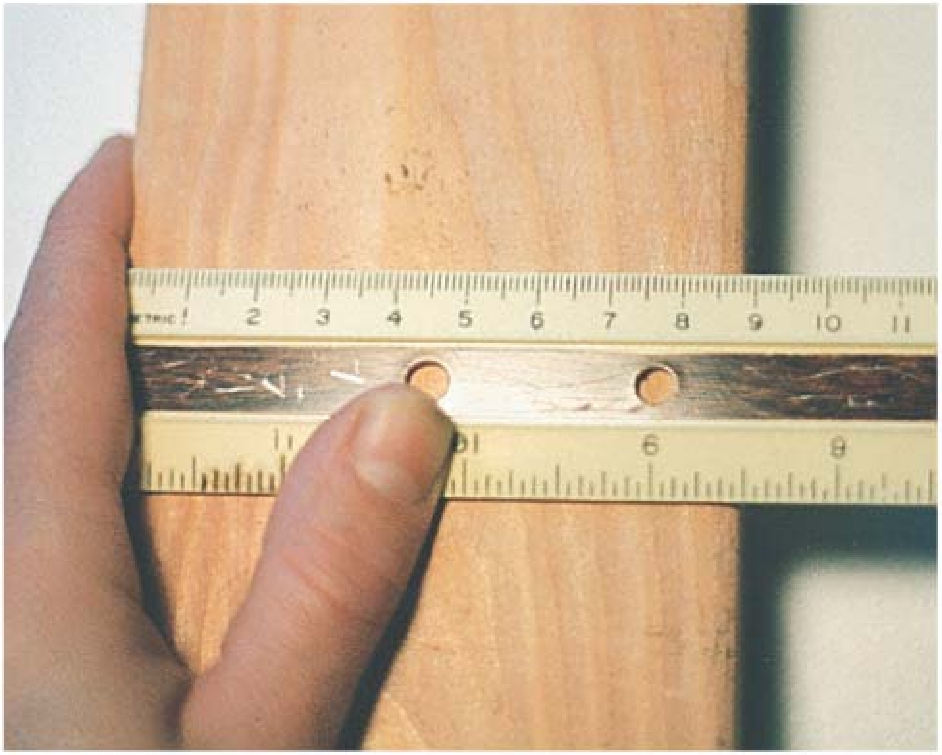
A **theory** is **detailed** and can give testable **predictions**.

A **law** is a brief description of how nature behaves in a broad set of circumstances.

A **principle** is similar to a law, but applies to a narrower range of phenomena.

1-3 Measurement and Uncertainty; Significant Figures

No measurement is exact; there is always some **uncertainty** due to limited instrument accuracy and difficulty reading results.



The photograph to the left illustrates this – it would be difficult to measure the width of this board more accurately than **± 1 mm.**

1-3 Measurement and Uncertainty; Significant Figures

Estimated uncertainty is written with a ± sign; for example: **8.8 ± 0.1 cm.**

Percent uncertainty is the ratio of the uncertainty to the measured value, multiplied by 100:

$$\frac{0.1}{8.8} \times 100\% \approx 1\%.$$

1-3 Measurement and Uncertainty; Significant Figures

The number of significant figures is the number of reliably known digits in a number. It is usually possible to tell the number of significant figures by the way the number is written:

23.21 cm has four significant figures.

0.062 cm has two significant figures (the initial zeroes don’t count).

80 km is ambiguous—it could have one or two significant figures. If it has three, it should be written 80.0 km.

1-3 Measurement and Uncertainty; Significant Figures

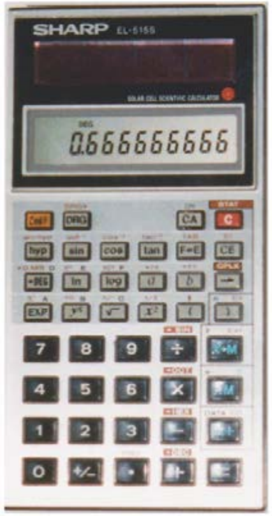
When multiplying or dividing numbers, the result has as many significant figures as the number used in the calculation with the fewest significant figures.

Example: 11.3 cm x 6.8 cm = 77 cm.

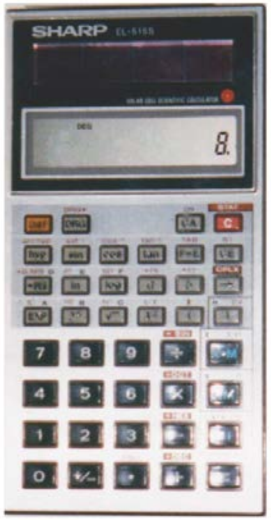
When adding or subtracting, the answer is no more accurate than the least accurate number used.

The number of significant figures may be off by one; use the percentage uncertainty as a check.

1-3 Measurement and Uncertainty; Significant Figures



Calculators will not give you the right number of significant figures; they usually give too **many** but sometimes give too **few** (especially if there are trailing zeroes after a decimal point).



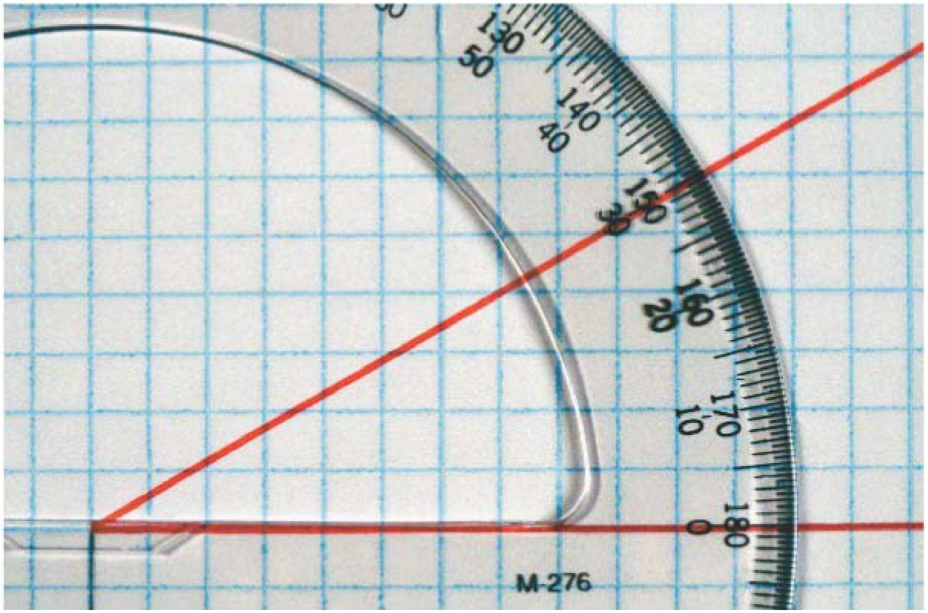
The top calculator shows the result of 2.0/3.0.

The bottom calculator shows the result of 2.5 x 3.2.

1-3 Measurement and Uncertainty; Significant Figures

Conceptual Example 1-1: Significant figures.

Using a protractor, you measure an angle to be 30°. (a) How many **significant figures** should you quote in this measurement? (b) Use a calculator to find the cosine of the angle you measured.



1-3 Measurement and Uncertainty; Significant Figures

Scientific notation is commonly used in physics; it allows the number of **significant figures** to be clearly shown.

For example, we cannot tell how many significant figures the number 36,900 has. However, if we write 3.69 x 10^4, we know it has **three**; if we write 3.690 x 10^4, it has **four**.

Much of physics involves **approximations**; these can affect the precision of a measurement also.

1-3 Measurement and Uncertainty; Significant Figures

Accuracy vs. Precision

Accuracy is how **close** a measurement comes to the true value.

Precision is the **repeatability** of the measurement using the same instrument.

It is possible to be accurate without being precise and to be precise without being accurate!

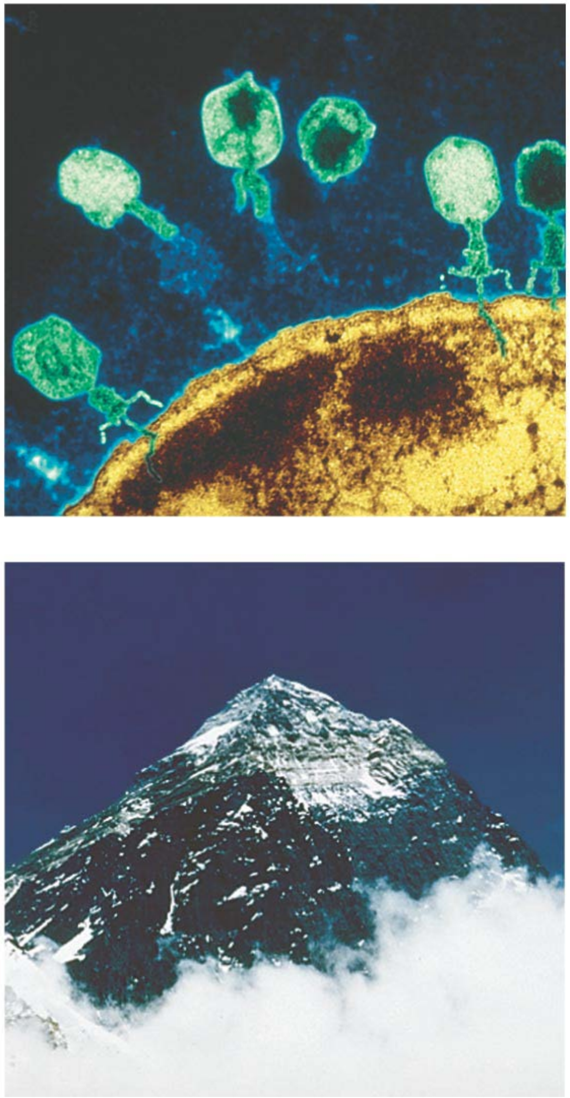
1-4 Units, Standards, and the SI System

Quantity	Unit	Standard
Length	Meter	Length of the path traveled by light in 1/299,792,458 second
Time	Second	Time required for 9,192,631,770 periods of radiation emitted by cesium atoms
Mass	Kilogram	Platinum cylinder in International Bureau of Weights and Measures, Paris

1-4 Units, Standards, and the SI System

TABLE 1–1 Some Typical Lengths or Distances
(order of magnitude)

Length (or Distance)	Meters (approximate)
Neutron or proton (diameter)	10^{-15} m
Atom (diameter)	10^{-10} m
Virus [see Fig. 1–5a]	10^{-7} m
Sheet of paper (thickness)	10^{-4} m
Finger width	10^{-2} m
Football field length	10^{2} m
Height of Mt. Everest [see Fig. 1–5b]	10^{4} m
Earth diameter	10^{7} m
Earth to Sun	10^{11} m
Earth to nearest star	10^{16} m
Earth to nearest galaxy	10^{22} m
Earth to farthest galaxy visible	10^{26} m



1-4 Units, Standards, and the SI System

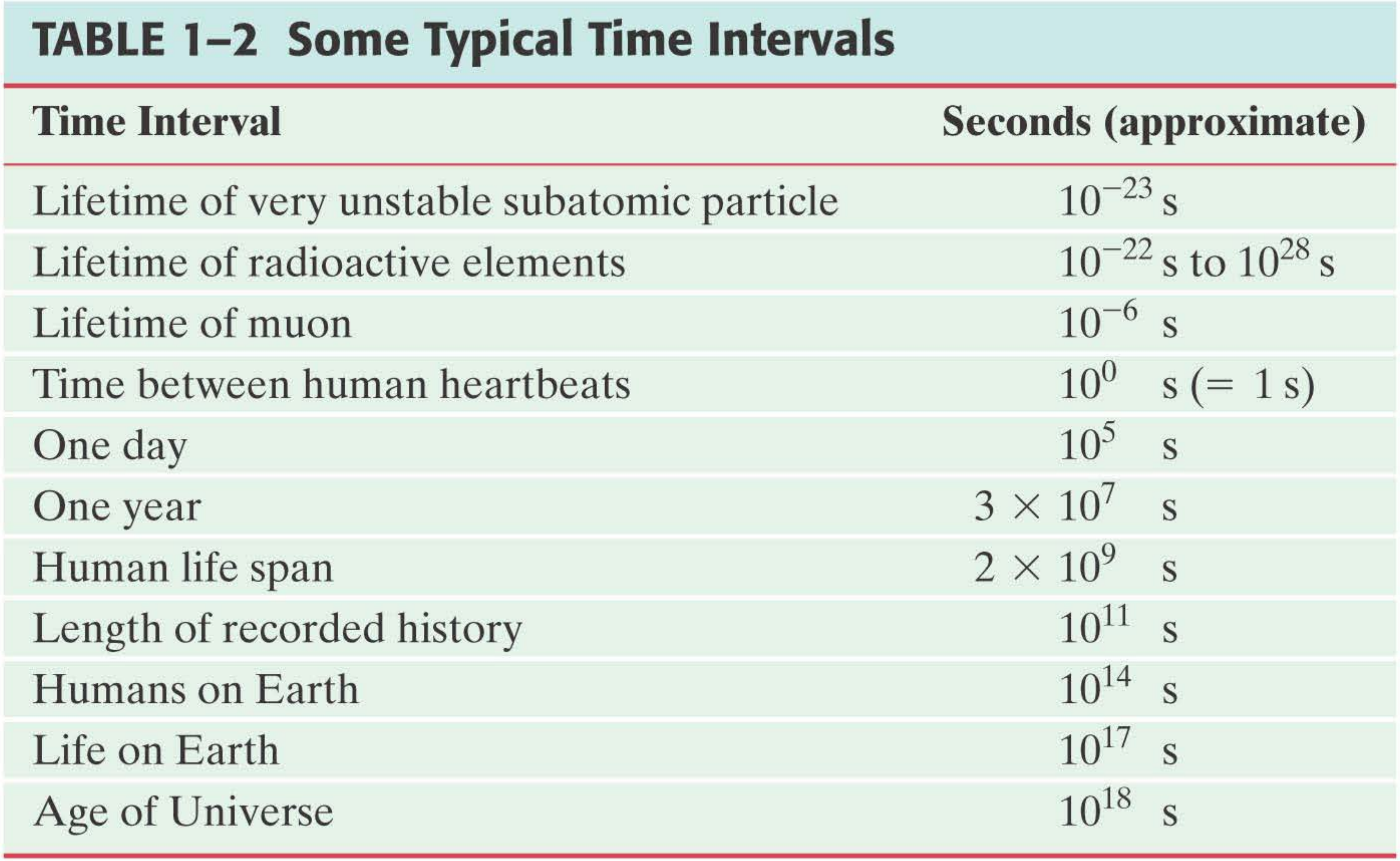


TABLE 1–2 Some Typical Time Intervals

Time Interval	Seconds (approximate)
Lifetime of very unstable subatomic particle	10^{-23} s
Lifetime of radioactive elements	10^{-22} s to 10^{28} s
Lifetime of muon	10^{-6} s
Time between human heartbeats	10^{0} s (= 1 s)
One day	10^{5} s
One year	3×10^{7} s
Human life span	2×10^{9} s
Length of recorded history	10^{11} s
Humans on Earth	10^{14} s
Life on Earth	10^{17} s
Age of Universe	10^{18} s

1-4 Units, Standards, and the SI System

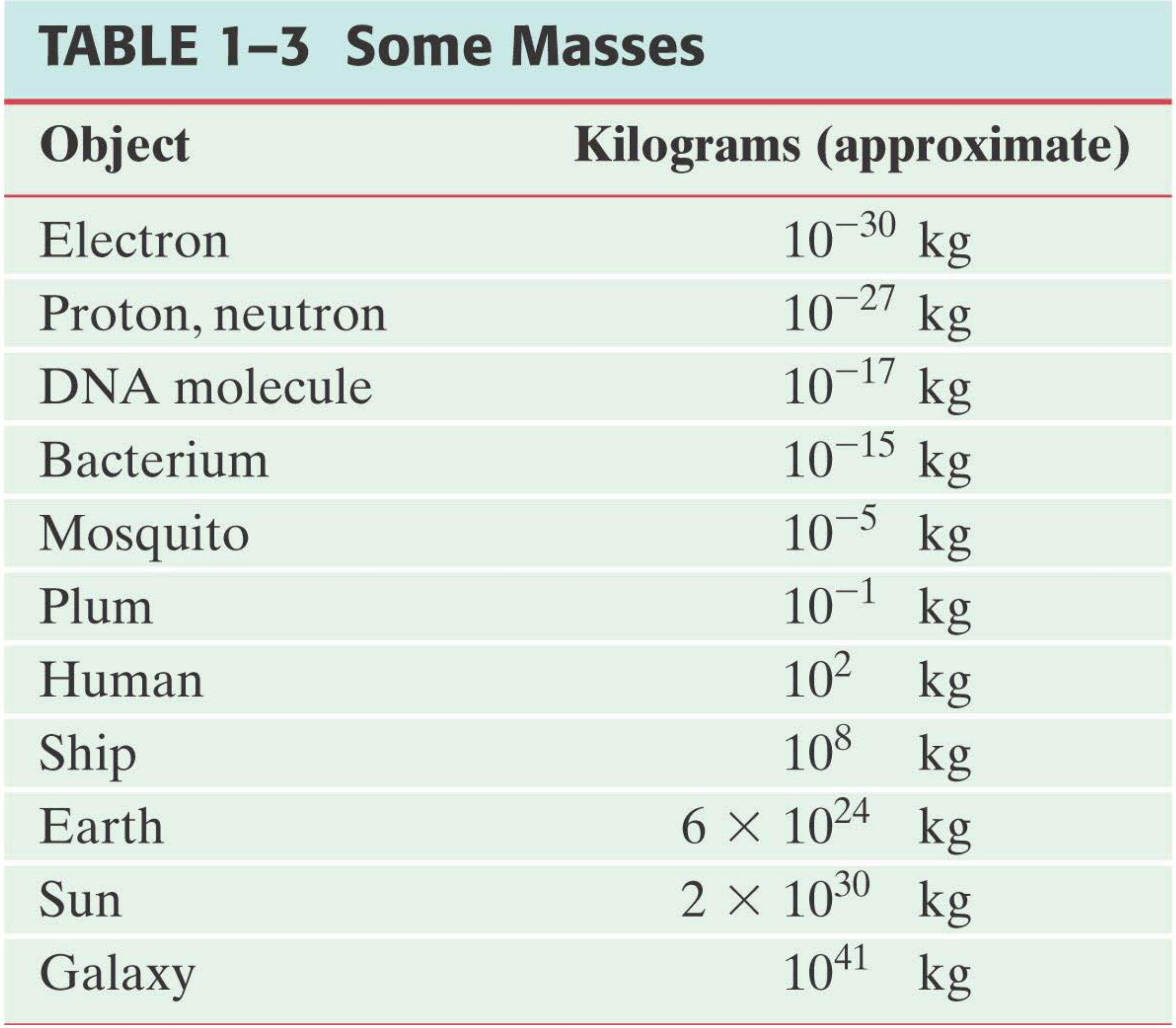


TABLE 1–3 Some Masses

Object	Kilograms (approximate)
Electron	10^{-30} kg
Proton, neutron	10^{-27} kg
DNA molecule	10^{-17} kg
Bacterium	10^{-15} kg
Mosquito	10^{-5} kg
Plum	10^{-1} kg
Human	10^{2} kg
Ship	10^{8} kg
Earth	6×10^{24} kg
Sun	2×10^{30} kg
Galaxy	10^{41} kg

1-4 Units, Standards, and the SI System

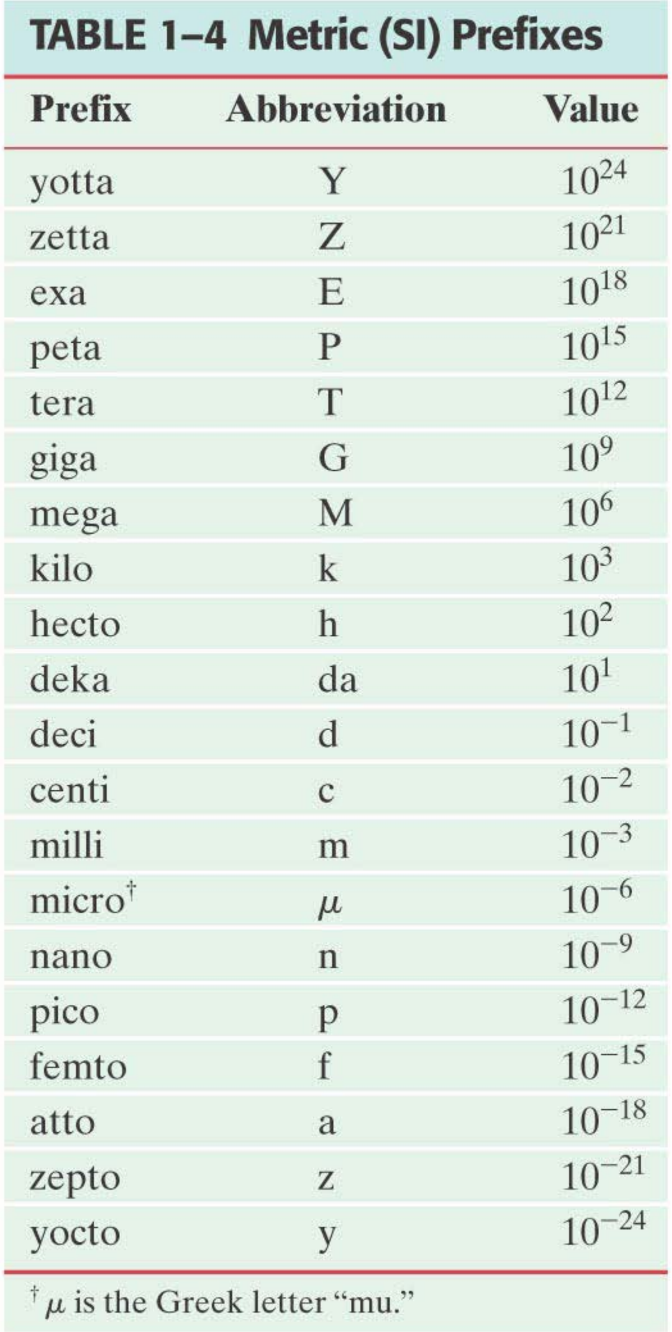


TABLE 1–4 Metric (SI) Prefixes

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."

These are the standard SI **prefixes** for indicating powers of 10. Many are familiar; yotta, zetta, exa, hecto, deka, atto, zepto, and yocto are rarely used.

1-4 Units, Standards, and the SI System

We will be working in the SI system, in which the basic units are **kilograms**, **meters**, and **seconds**. Quantities not in the table are **derived** quantities, expressed in terms of the **base** units.

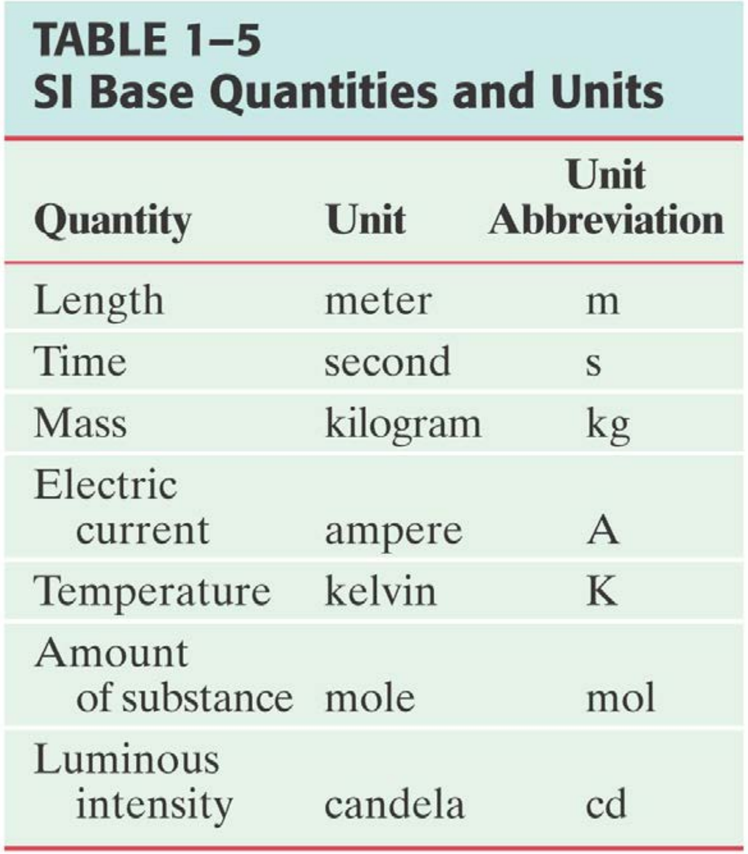


TABLE 1–5
SI Base Quantities and Units

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

Other systems: **cgs**; units are centimeters, grams, and seconds.

British engineering system has force instead of mass as one of its basic quantities, which are feet, pounds, and seconds.

1-5 Converting Units

Unit conversions always involve a conversion factor.

Example: 1 in. = 2.54 cm.

Written another way: 1 = 2.54 cm/in.

So if we have measured a length of 21.5 inches, and wish to convert it to centimeters, we use the conversion factor:

$$21.5 \text{ inches} = (21.5 \cancel{\text{in.}}) \times \left(2.54 \frac{\text{cm}}{\cancel{\text{in.}}}\right) = 54.6 \text{ cm.}$$

1-5 Converting Units

Example 1-2: The 8000-m peaks.

The fourteen tallest peaks in the world are referred to as “eight-thousanders,” meaning their summits are over 8000 m above sea level. What is the elevation, in **feet**, of an elevation of 8000 m?

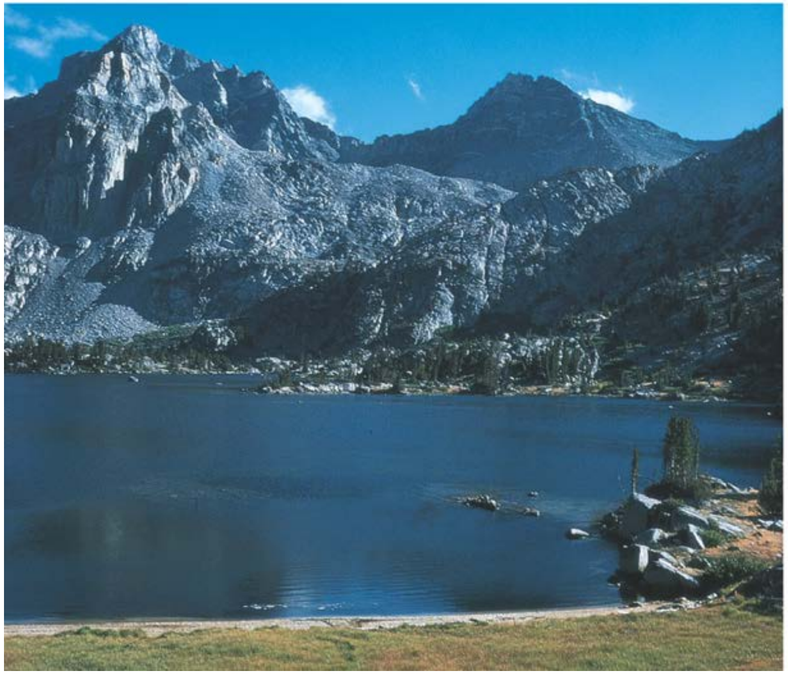
1-6 Order of Magnitude: Rapid Estimating

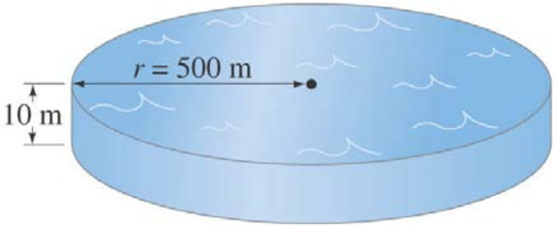
A quick way to **estimate** a calculated quantity is to round off all numbers to **one** significant figure and then calculate. Your result should at least be the right **order of magnitude**; this can be expressed by rounding it off to the nearest power of 10.

Diagrams are also very useful in making estimations.

1-6 Order of Magnitude: Rapid Estimating

Example 1-5: Volume of a lake.



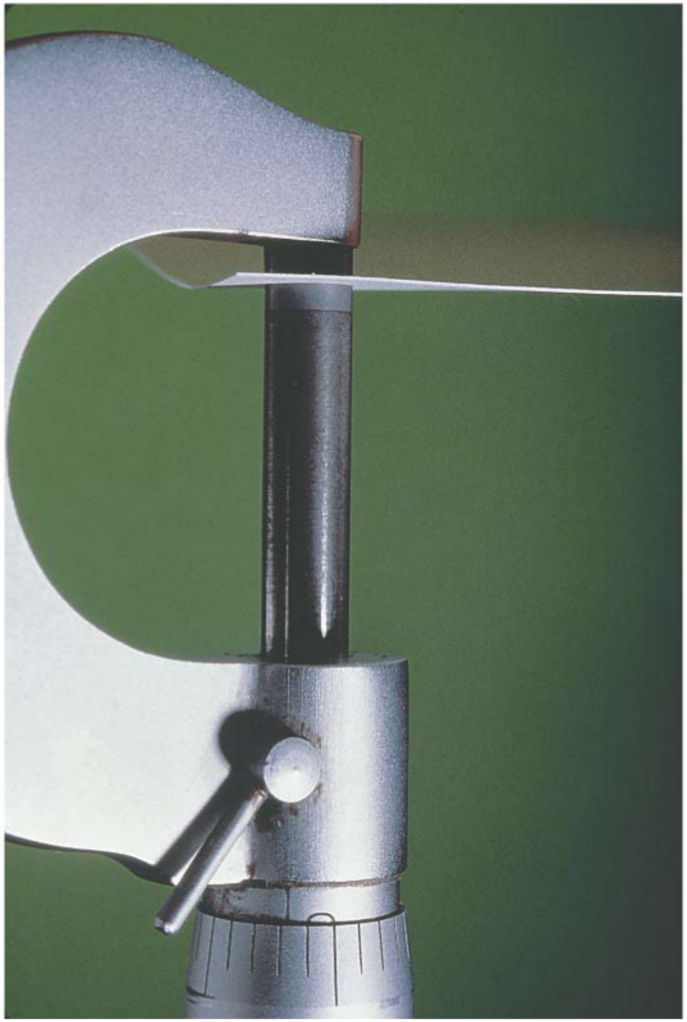


Estimate how much water there is in a particular lake, which is roughly circular, about 1 km across, and you guess it has an average depth of about 10 m.

1-6 Order of Magnitude: Rapid Estimating

Example 1-6: Thickness of a page.

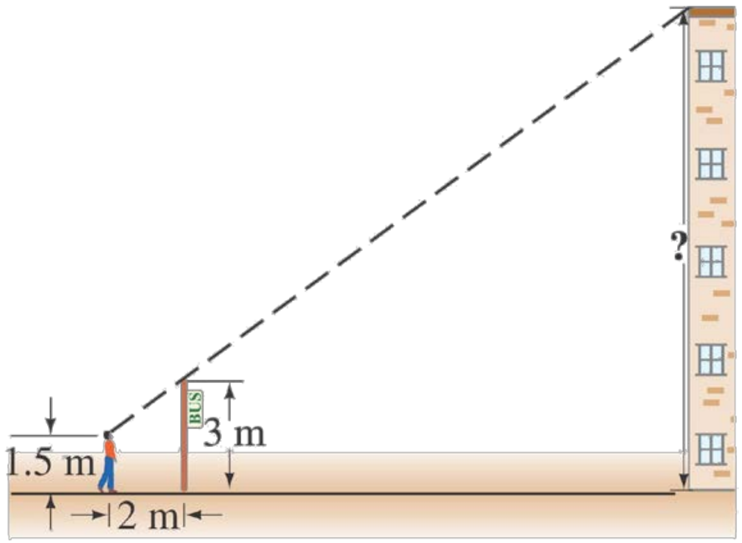
Estimate the thickness of a page of your textbook. (Hint: you don't need one of these!)

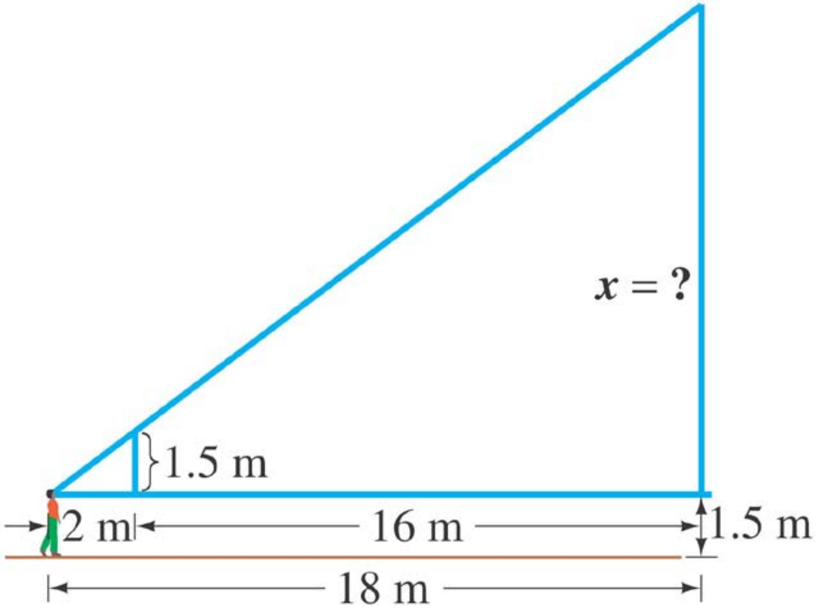


1-6 Order of Magnitude: Rapid Estimating

Example 1-7: Height by triangulation.

Estimate the height of the building shown by "triangulation," with the help of a bus-stop pole and a friend. (See how useful the diagram is!)

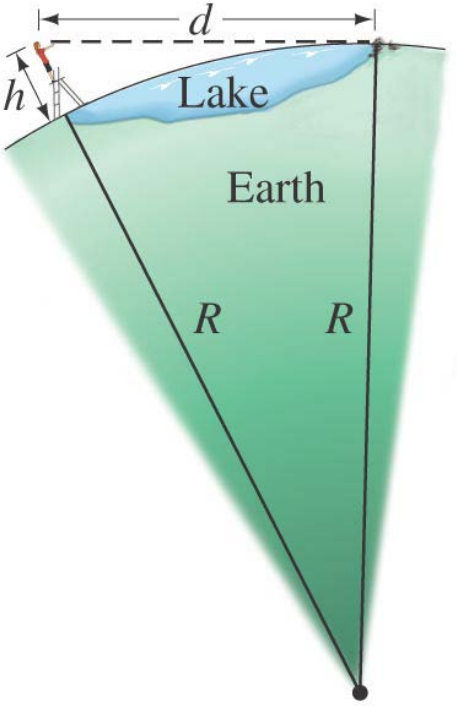




1-6 Order of Magnitude: Rapid Estimating

Example 1-8: Estimating the radius of Earth.

If you have ever been on the shore of a large lake, you may have noticed that you cannot see the beaches, piers, or rocks at water level across the lake on the opposite shore. The lake seems to bulge out between you and the opposite shore—a good clue that the Earth is round. Suppose you climb a stepladder and discover that when your eyes are 10 ft (3.0 m) above the water, you can just see the rocks at water level on the opposite shore. From a map, you estimate the distance to the opposite shore as $d \approx 6.1$ km. Use $h = 3.0$ m to estimate the radius R of the Earth.



1-7 Dimensions and Dimensional Analysis

Dimensions of a quantity are the **base units** that make it up; they are generally written using square brackets.

Example: Speed = distance/time

Dimensions of speed: [*L*/*T*]

Quantities that are being **added** or **subtracted** must have the same dimensions. In addition, a quantity calculated as the **solution** to a problem should have the correct dimensions.

1-7 Dimensions and Dimensional Analysis

Dimensional analysis is the checking of dimensions of all quantities in an equation to ensure that those which are added, subtracted, or equated have the **same** dimensions.

Example: Is this the **correct** equation for velocity?

$$v = v_0 + \tfrac{1}{2} a t^2.$$

Check the dimensions:

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

Wrong!

Summary of Chapter 1

- Theories are created to explain observations, and then tested based on their predictions.

- A model is like an analogy; it is not intended to be a true picture, but to provide a familiar way of envisioning a quantity.

- A theory is much more well developed, and can make testable predictions; a law is a theory that can be explained simply, and that is widely applicable.

- Dimensional analysis is useful for checking calculations.

Summary of Chapter 1

- **Measurements can never be exact; there is always some uncertainty. It is important to write them, as well as other quantities, with the correct number of significant figures.**

- **The most common system of units in the world is the SI system.**

- **When converting units, check dimensions to see that the conversion has been done properly.**

- **Order-of-magnitude estimates can be very helpful.**