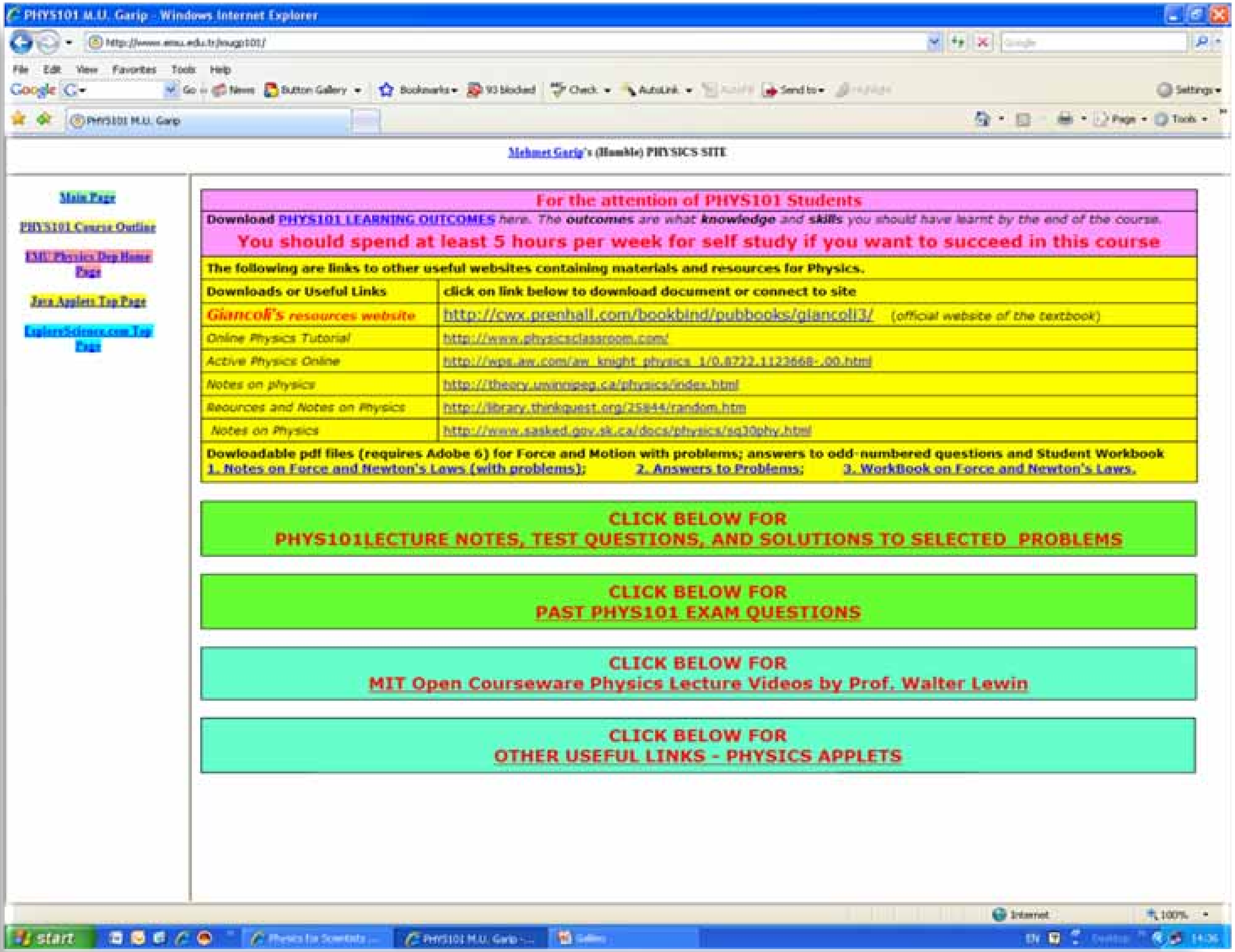
Phys 101

Spring 2010 – 2011

Dr Mehmet Garip's physics site

http://www.emu.edu.tr/mugp101



A Recipe for Success

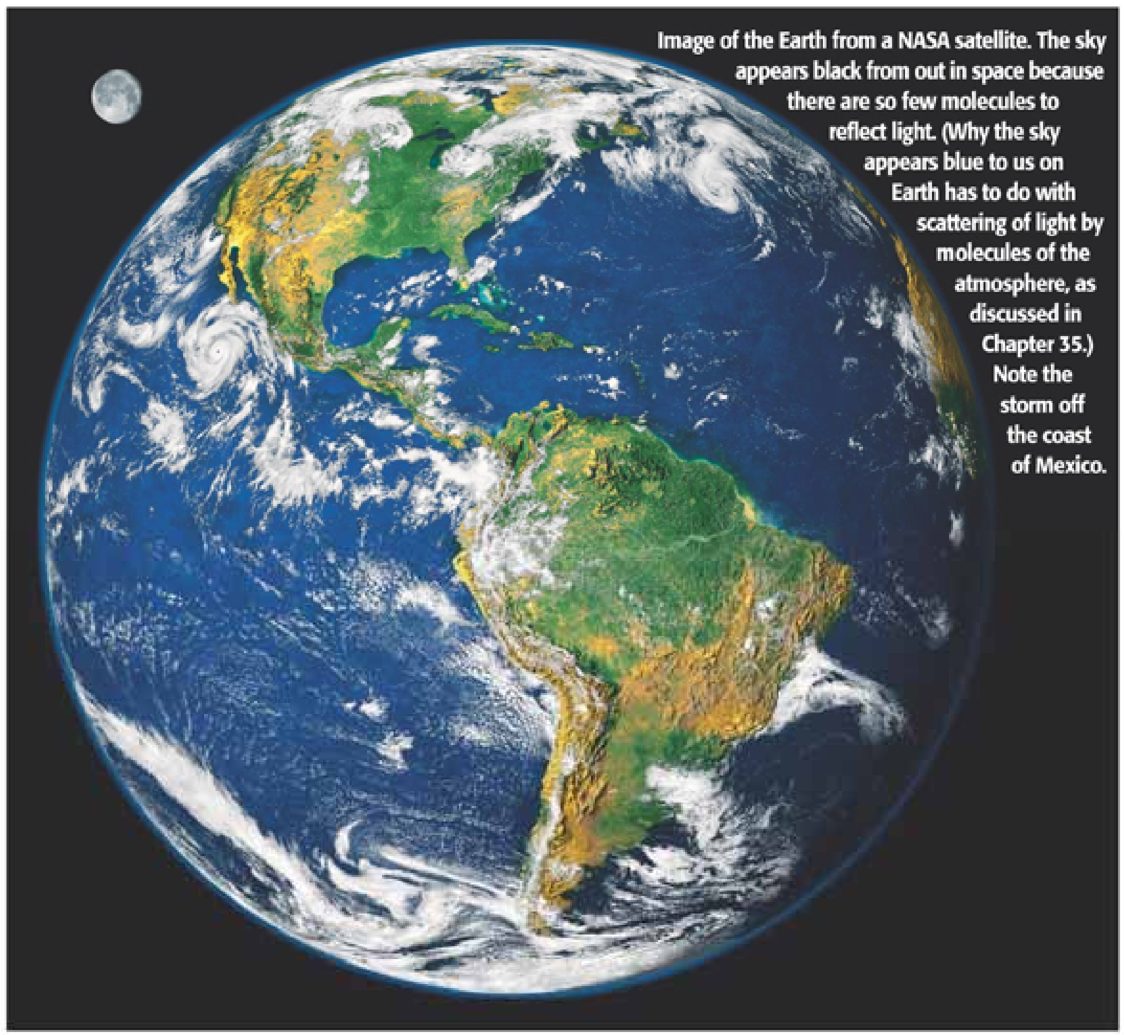
- ✓ **Take the course seriously**, starting on the first day. **Attend every lecture**.
- ✓ **Take an active part in class**. Feel free to speak up and ask questions.
- ✓ It is important that **you must be well prepared for lecture**. Prior to each lecture, check the syllabus to see what will be covered.
- ✓ Read with a pen and notebook. **Take notes** while you read, and work out example problems.
- ✓ **Don’t get isolated**: Get in a study group.
- ✓ **Go to office hours**.

A Recipe for Success

- ✓ **Don't try solving problems without studying the chapter first.**
- ✓ **Don't fall behind**; it will be very difficult to catch up.
- ✓ Just reading the text, attending the lecture, and doing the homework is not enough. You have to understand the material (Test of understanding: If you can explain the material, without referring to the text, then you understand). **This course is <u>not</u> about memorizing; it's about understanding.**

Chapter 1

Introduction, Measurement, Estimating



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

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.

▲ (a) This Roman aqueduct was built 2000 years ago and still stands. (b) The Hartford Civic Center collapsed in 1978, just two years after it was built.

1-2 Models, Theories, and Laws

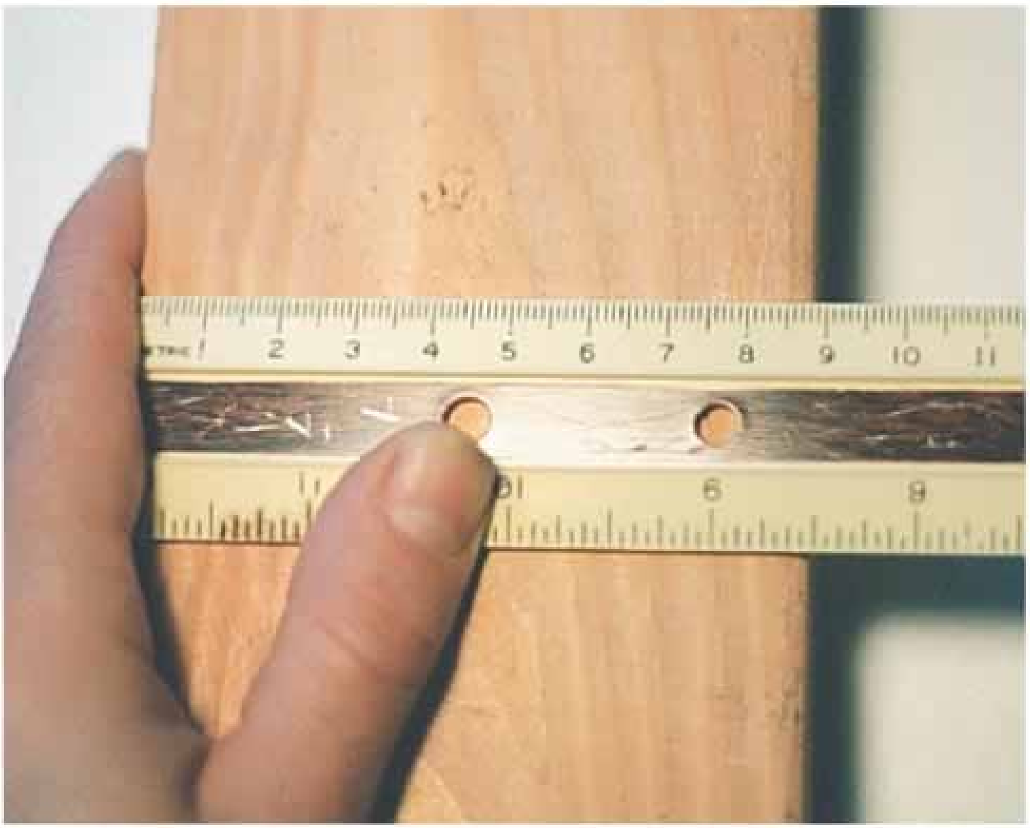
Models are very useful during the process of understanding phenomena. A model creates mental pictures; care must be taken to understand the limits of the model and not take it too seriously.

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.

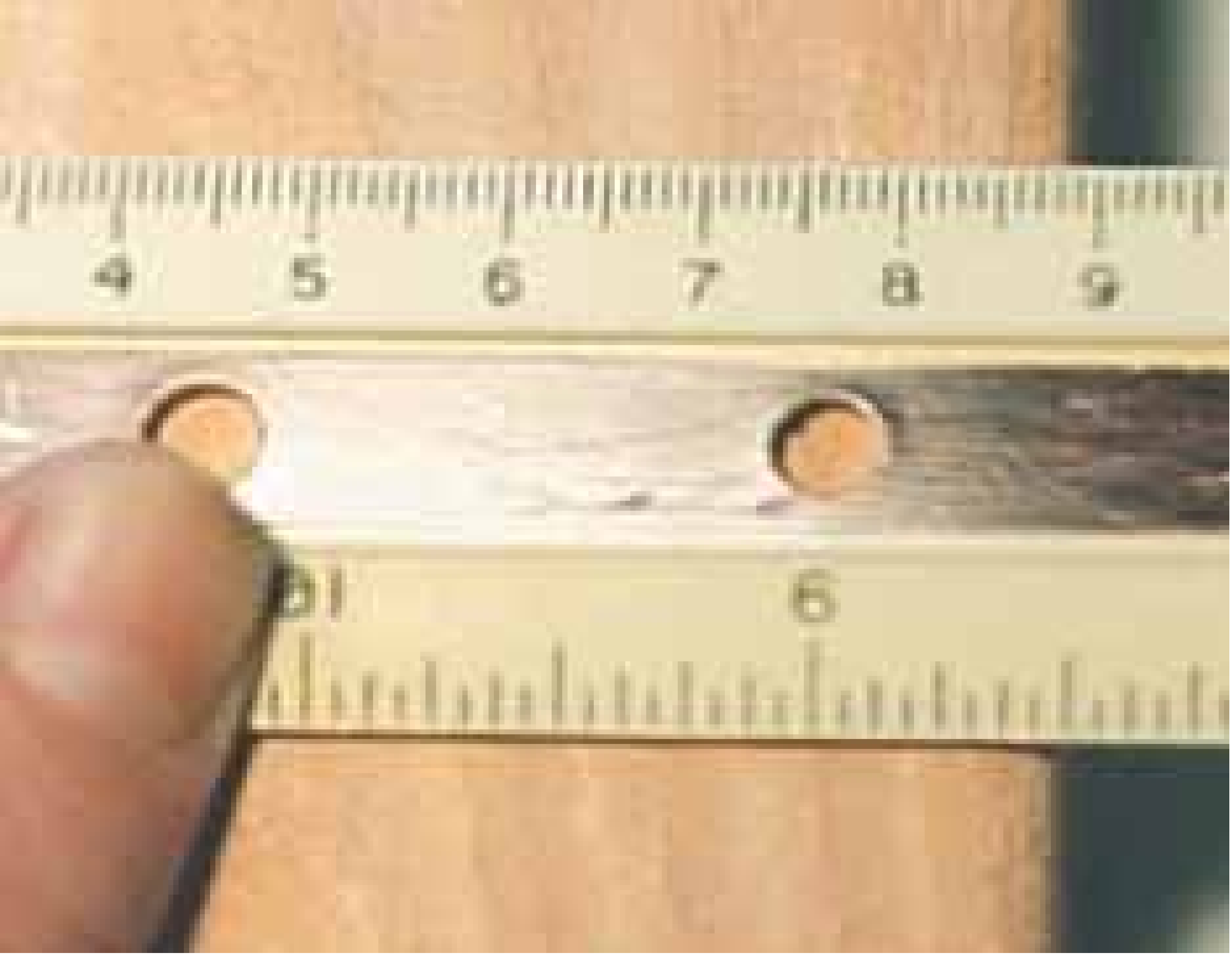
A principle is similar to a law, but applies to a narrower range of phenomena.

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.


4 5 6 7 8 9
6

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

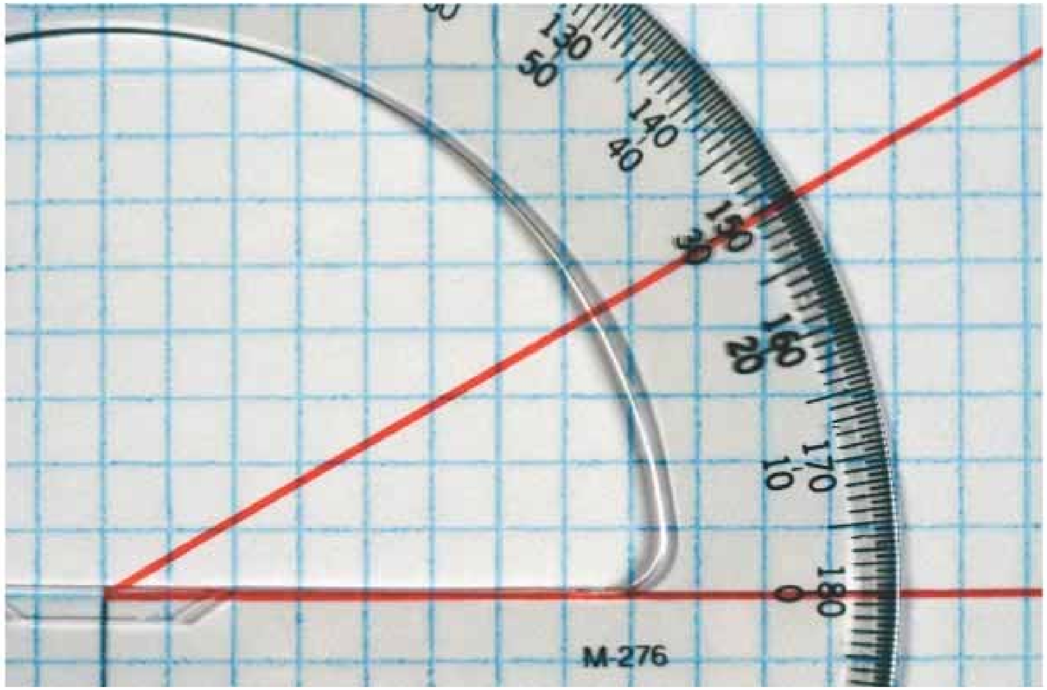
When multiplying or dividing numbers, the result has as many significant figures as the number used in the calculation with the fewest significant figures.

Example: 11.3 cm x 6.8 cm = 77 cm.

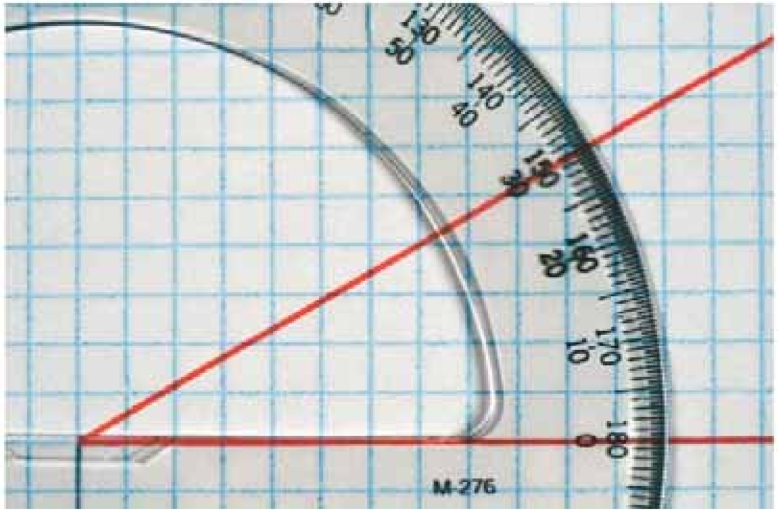
When adding or subtracting, the answer is no more accurate than the least accurate number used.

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



Response: (a) If you look at a protractor, you will see that the precision with which you can measure an angle is about one degree (certainly not 0.1°). So you can quote two significant figures, namely, 30° (not 30.0°). (b) If you enter cos 30° in your calculator, you will get a number like 0.866025403. However, the angle you entered is known only to two significant figures, so its cosine is correctly given by 0.87; you must round your answer to two significant figures.

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 3.69×10^4, we know it has three; if we write 3.690×10^4, it has four.

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!

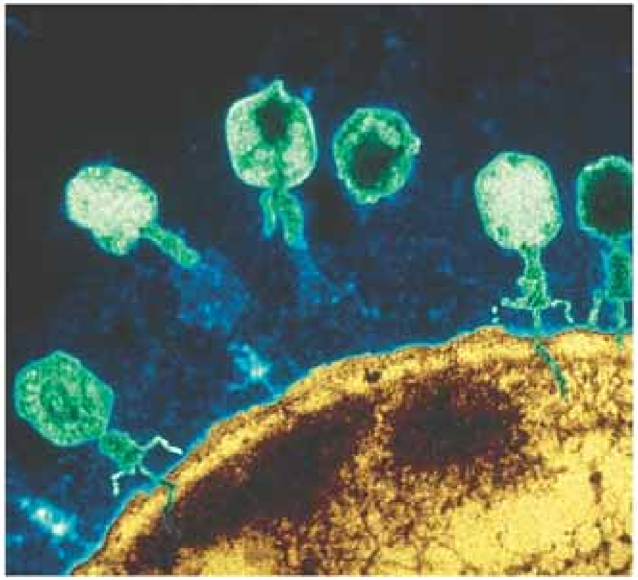
1-4 Units, Standards, and the SI System

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

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:

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

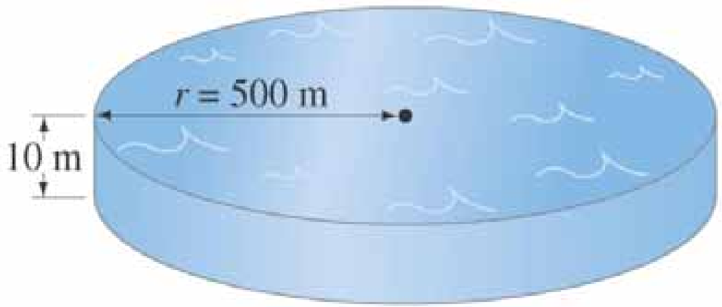
1-6 Order of Magnitude: Rapid Estimating

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.

Answer:

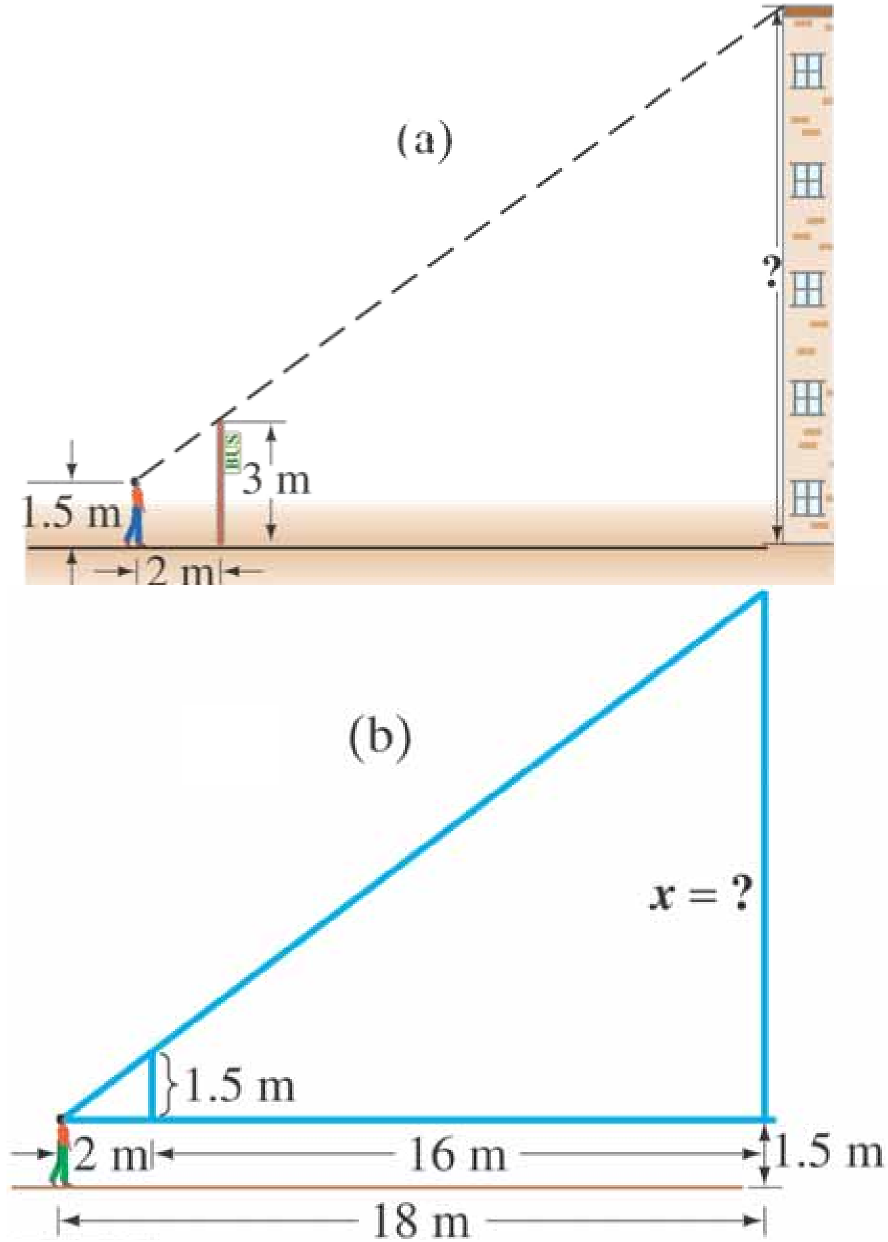
$$V = \pi r^2 h \approx (3)(500\text{ m})^2\,(10\text{m})$$

$$\approx 8 \times 10^6\text{ m}^3 \approx 10^7\text{ m}^3 .$$

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!)



Answer: The building is about 15 m tall.

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?

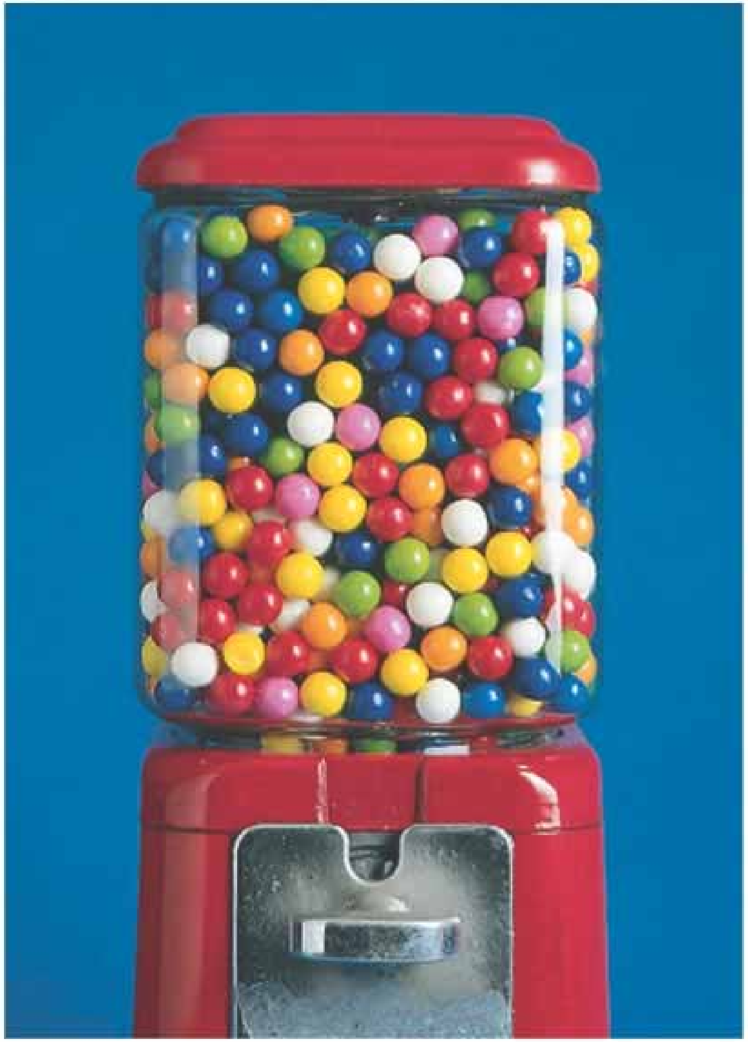
$$v = v_0 + \tfrac{1}{2}at^2.$$

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!

Problem 48



◀ Estimate the number of gumballs in the machine.

SOLUTION. Counting gumballs across the bottom, there are about 10 in a row. Thus we estimate that one layer contains about 100 gumballs. In counting vertically, we see that there are about 15 rows. Thus we estimate that there are 1500 gumballs in the machine.

Problem 65

The American Lung Association gives the following formula for an average person's expected lung capacity *V* (in liters):

$$V = 4.1\,H - 0.018\,A - 2.69$$

where *H* and *A* are the person's height (in meters), and age (in years), respectively. In this formula, what are the units of the numbers 4.1, 0.018, and 2.69?

SOLUTION. The units for each term must be in liters, since the volume is in liters.

$$[\text{units of } 4.1][\text{m}] = [\text{liters}] \quad \rightarrow \quad \boxed{[\text{units of } 4.1] = \frac{\text{liters}}{\text{m}}}$$

$$[\text{units of } 0.018][\text{years}] = [\text{liters}] \quad \rightarrow \quad \boxed{[\text{units of } 0.018] = \frac{\text{liters}}{\text{year}}}$$

$$\boxed{[\text{units of } 2.69] = \text{liters}}$$