1. What is **science**?

   Latin: *scientia* = knowledge
   i) science vs. art
   ii) natural vs. social sciences
   iii) fundamental/pure vs. applied

2. What is a **scientific method**?

   i) investigation/observation
   ii) formulation and testing of hypotheses
   iii) experiment/reproduction

3. What is a theory? (common language vs. **science**)

   i) mathematical or logical explanation
   ii) can be tested
   iii) make predictions

Theories can be improved and replaced
Physics

What is physics? Study of matter, energy, and the interaction between them

Classical physics and Modern physics up to the XIX and XX and XXI

Classical mechanics, Electromagnetism, Relativity, Thermodynamics, Statistical Mechanics, Quantum Mechanics

What is the relation between physics and other fields?

Contributions to physics from physics
Physiologist Luigi Galvani MRI
(book - page 4)
Botanist Robert Brown radiation therapy
(http://en.wikipedia.org/wiki/Brownian_motion)
Bohr and Einstein in Paul Ehrenfest's home, Brussels, 1930
Measurements - important part of physics
- have uncertainty associated
  (accuracy/limitations of instruments)

Estimated uncertainty  \( 5.2 \pm 0.1 \text{ cm} \)

Percent uncertainty \[ \frac{0.1}{5.2} \approx 0.02 = 2\% \]

Diamond  \( 8.17 \pm 0.05 \text{ g} \)

How do we compute the percent uncertainty?
If we weigh it and get 8.09 g, could it be the same diamond?

a) \( 0.05/8.17 \) and NO          b) \( 0.05/8.17 \) and YES

\( \text{c) } 8.17/0.05 \) and YES     d) \( 8.17/0.5 \) and NO
**Significant Figures**

**Significant figures** - number of reliably known digits in a number

- 23.21 cm – four
- 23.210 cm - five
- 0.062 cm - two
- 80 km - one or two (80. km)
- 80.0 km - three

**Do not keep more digits than justified**

Area of rectangle: 11.3 cm by 6.8 cm

\[ 11.3 \times 6.8 = 76.84, \quad \text{but} \quad 11.2 \times 6.7 = 75.04 \quad \text{and} \quad 11.4 \times 6.9 = 78.66 \]

therefore the area is \( 77 \, \text{cm}^2 \)

**General rule for the number of significant digits of a result:**

- Multiplication and division: as many digits as the number with the least number of significant figures
- Addition and subtraction: result no more accurate than the least accurate number used

\[ 2355.242 + 23.57 = 2378.812 \]
Scientific notation – write numbers in powers of ten

2321 = 2.321 \times 10^3; \quad 0.0062 = 6.2 \times 10^{-3}

Depending on the accuracy

\begin{align*}
36900 \quad & \begin{cases} 
3.69 \times 10^4 \\
3.690 \times 10^4 \\
3.6900 \times 10^4
\end{cases}
\end{align*}
**Units, Standards, and the SI System**

Measurement is made relative to a **standard/unit**

The International System of Units (SI system)

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Length (or Distance)</td>
<td>Meters (approximate)</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td>Neutron or proton (radius)</td>
<td>$10^{-15}$ m</td>
<td></td>
</tr>
<tr>
<td>Atom</td>
<td>$10^{-10}$ m</td>
<td></td>
</tr>
<tr>
<td>Virus [see Fig. 1–8a]</td>
<td>$10^{-7}$ m</td>
<td></td>
</tr>
<tr>
<td>Sheet of paper (thickness)</td>
<td>$10^{-4}$ m</td>
<td></td>
</tr>
<tr>
<td>Finger width</td>
<td>$10^{-2}$ m</td>
<td></td>
</tr>
<tr>
<td>Football field length</td>
<td>$10^{2}$ m</td>
<td></td>
</tr>
<tr>
<td>Height of Mt. Everest [see Fig. 1–8b]</td>
<td>$10^{4}$ m</td>
<td></td>
</tr>
<tr>
<td>Earth diameter</td>
<td>$10^{7}$ m</td>
<td></td>
</tr>
<tr>
<td>Earth to Sun</td>
<td>$10^{11}$ m</td>
<td></td>
</tr>
<tr>
<td>Earth to nearest star</td>
<td>$10^{16}$ m</td>
<td></td>
</tr>
<tr>
<td>Earth to nearest galaxy</td>
<td>$10^{22}$ m</td>
<td></td>
</tr>
<tr>
<td>Earth to farthest galaxy visible</td>
<td>$10^{26}$ m</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Modern measurements of the Earth’s circumference reveal that the intended length is one-fiftieth of 1%. Not bad!

\(^2\) The new definition of the meter has the effect of giving the speed of light the exact value $299,792,458 \text{ m s}$.  

---

**TABLE 1–4** Metric (SI) Prefixes

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

\(^3\) μ is the Greek letter “mu.”

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Time

**Sundial**: 16th century BC, Egypt

**Sandglass**: 14th century

**Time**

1s = frequency of radiation emitted by cesium atoms between two particular states.

There are 60s in one minute (min) and 60 min in one hour (h).

2 min = (2 min) (1) = (2 min) \( \left( \frac{60 \text{s}}{1 \text{min}} \right) \) = 120 s
Conversion factors:

1 km = 1000 m
1 h = 3600 s
1 mi = 1609 m (mi – miles)
1 in. = 2.54 cm (in. – inches)
1 ft = 12 in. (ft – foot)
1 mi = 5280 ft

Example:
Convert 55 mi/h (or mph) to meters per second (m/s)

\[
55 \frac{\text{mi}}{\text{h}} = \left( 55 \frac{\text{mi}}{\text{h}} \right) \left( \frac{1609 \text{m}}{\text{mi}} \right) \left( \frac{\text{h}}{3600 \text{s}} \right) = 25 \frac{\text{m}}{\text{s}}
\]

In class:
convert 5.0 m/s to km/h

\[
5 \frac{\text{m}}{\text{s}} = \left( 5 \frac{\text{m}}{\text{s}} \right) \left( \frac{0.001 \text{km}}{\text{m}} \right) \left( \frac{3600 \text{s}}{\text{h}} \right) = 18 \frac{\text{km}}{\text{h}}
\]
Rough estimate made by rounding off all numbers to one significant figure

1. Estimate the volume of our textbook
   width: 20 cm       height: 30 cm       depth: 2 cm
   \[ V \approx (20\text{cm}) \times (30\text{cm}) \times (2\text{cm}) = 1 \times 10^3 \text{cm}^3 \]

2. Estimate the thickness of a piece of paper of our textbook
   1 piece of paper = 2 pages
   book has around 500 pages and is about 2 cm thick
   \[ \begin{align*}
   &1 \text{ piece of paper } \rightarrow x \\
   &250 \text{ pieces } \rightarrow 2\text{cm}
   \end{align*} \]
   \[ x = \frac{2\text{cm}}{250} = 0.008\text{cm} \approx 0.1\text{mm} \]
Dimensional analysis
useful technique to check if a relationship is incorrect

Position x is given in $m$
Time t is given in $s$
Velocity v is given in $m/s$
Acceleration a is given in $m/s^2$

$v = at^2$ Dimensionally **WRONG**!

$v = at$ Dimensionally **right**
1. Exercises
A: Calculate the area of a rectangle 4.5 cm by 3.25 cm
B: Do 0.00324 and 0.00056 have the same number of significant figures?
C: How many significant figures are in 1.23, 0.123, 0.0123

2. Would a driver at 15m/s in a 35mi/h zone be exceeding the speed limit?
Measurement – uncertainty; **significant figures**

**Scientific notation**

**Units, SI:** meter, kilogram, second

**Converting units**

---

**Dimensional Analysis**

useful way to find out if an equation is **INCORRECT**

Time $t$ is given in $s$

Velocity $v$ is given in $m/s$

Acceleration $a$ is given in $m/s^2$

\[ v = at^2 \]  Dimensionally **WRONG**!

\[ v = at \]  Dimensionally **right**