Class Webpage

• My webpage: [http://rjm.physics.rutgers.edu/](http://rjm.physics.rutgers.edu/)
  – Contact information
  – Office hours
  – Teaching/Research Links

• Class webpage: [https://rjm.physics.rutgers.edu/Teaching/Summer2017/203/](https://rjm.physics.rutgers.edu/Teaching/Summer2017/203/)

• Syllabus
  – Announcements
  – “Reading Assignments”
  – Grades
Syllabus

• Online: [https://rjm.physics.rutgers.edu/Teaching/Summer2017/203/syllabus.php](https://rjm.physics.rutgers.edu/Teaching/Summer2017/203/syllabus.php)
  – Lecture Schedule
  – Exam Schedule
• The Nature of Science
• Physics and Its Relation to Other Fields
• 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
• Vectors and Scalars
• Addition of Vectors—Graphical Methods
• Subtraction of Vectors, and Multiplication of a Vector by a Scalar
• Adding Vectors by Components
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.
The Nature of Science

How does a new theory get accepted?

- Predictions agree better with data
- Explains a greater range of phenomena
Physics and Its Relation to Other Fields

Physics is needed in both architecture and engineering.

Other fields that use physics, and make contributions to it: physiology, zoology, life sciences, …
Physics and Its Relation to Other Fields

Communication between architects and engineers is essential if disaster is to be avoided.
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.
No measurement is exact; there is always some uncertainty due to limited instrument accuracy and difficulty reading results.

The photograph below illustrates this—it would be difficult to measure the width of this 2×4 to better than a millimeter.
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:

$$\frac{0.1}{8.8} \times 100\% \approx 1\%$$
Measurement and Uncertainty; Significant Figures

The number of significant figures is the number of reliably known digits in a number. The way the number is written should indicate the number of significant figures:

- 23.21 cm has 4 significant figures
- 0.062 cm has 2 significant figures (the initial zeroes don’t count)
- How many sig. figs in 80 km?
- 80 km is ambiguous—it could have 1 or 2 significant figures. If it has 3, it should be written 80.0 km.
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: $11.3 \text{ cm} \times 6.8 \text{ cm} = 77 \text{ cm}$

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

• 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 $3.69 \times 10^4$, we know it has three; if we write $3.690 \times 10^4$, it has four.

• Much of physics involves approximations; these can affect the precision of a measurement also.
## Units, Standards, and the SI System

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Meter</td>
<td>Length of the path traveled by light in $1/299,792,458$ second</td>
</tr>
<tr>
<td>Time</td>
<td>Second</td>
<td>Time required for $9,192,631,770$ periods of radiation emitted by cesium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>atoms</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram</td>
<td>Platinum cylinder in International Bureau of Weights and Measures, Paris</td>
</tr>
</tbody>
</table>
Units, Standards, and the SI System

These are the standard SI prefixes for indicating powers of 10. Many are familiar; Y, Z, E, h, da, a, z, and y are rarely used.

<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>
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<tr>
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<td>h</td>
<td>$10^{2}$</td>
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<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>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>pico</td>
<td>p</td>
<td>$10^{-12}$</td>
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<td>femto</td>
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<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>

†μ is the Greek letter “mu.”
Units, Standards, and the SI System

We will be working (mostly) in the SI system, where the basic units are kilograms, meters, and seconds.

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

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

Converting between metric units, for example from kg to g, is easy, as all it involves is powers of 10.

Converting to and from British units is slightly more work.

For example, given that
1 m = 3.28084 ft, this
8611-m mountain is
28251 feet high.
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.
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.*
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?

\[ v = v_0 + \frac{1}{2}at^2. \]

Check the dimensions:

\[
\begin{bmatrix} \frac{L}{T} \end{bmatrix} = \begin{bmatrix} \frac{L}{T} \end{bmatrix} + \begin{bmatrix} \frac{L}{T^2} \end{bmatrix}[T^2] = \begin{bmatrix} \frac{L}{T} \end{bmatrix} + [L].
\]

Wrong!
Vectors and Scalars

A vector has magnitude as well as direction.

Some vector quantities: displacement, velocity, force, momentum

A scalar has only a magnitude.

Some scalar quantities: mass, time, temperature
Addition of Vectors—Graphical Methods

For vectors in one dimension, simple addition and subtraction are all that is needed.

You do need to be careful about the signs, as the figure indicates.
Addition of Vectors—Graphical Methods

If the motion is in two dimensions, the situation is somewhat more complicated.

Here, the actual travel paths are at right angles to one another; we can find the displacement by using the Pythagorean Theorem.
Does adding the vectors in the opposite order give the same result?
Even if the vectors are not at right angles, they can be added graphically by using the "tail-to-tip" method.
The parallelogram method may also be used; here again the vectors must be “tail-to-tip.”

(a) Tail-to-tip

= (b) Parallelogram

≠ (c) Wrong
Subtraction of Vectors, and Multiplication of a Vector by a Scalar

In order to subtract vectors, we define the negative of a vector, which has the same magnitude but points in the opposite direction.

\[ \vec{V} + (-\vec{V}) = \vec{0} \]

Then we add the negative vector:

\[ \vec{v}_2 - \vec{v}_1 = \vec{v}_2 + (-\vec{v}_1) = \vec{v}_2 - \vec{v}_1 \]
Subtraction of Vectors, and Multiplication of a Vector by a Scalar

A vector $\vec{V}$ can be multiplied by a scalar $c$; the result is a vector $c\vec{V}$ that has the same direction but a magnitude $cV$.

If $c$ is negative, the resultant vector points in the opposite direction.

$\vec{V}$

$\vec{V}_2 = 1.5 \vec{V}$

$\vec{V}_3 = -2.0 \vec{V}$
Adding Vectors by Components

Any vector can be expressed as the sum of two other vectors, which are called its components. Usually the other vectors are chosen so they are perpendicular to each other.
Adding Vectors by Components

If the components are perpendicular, they can be found using trigonometric functions.

\[
\sin \theta = \frac{V_y}{V} \\
\cos \theta = \frac{V_x}{V} \\
\tan \theta = \frac{V_y}{V_x} \\
V^2 = V_x^2 + V_y^2
\]
Adding Vectors by Components

The components are effectively one-dimensional, so they can be added arithmetically:

\[ \vec{V}_R = \vec{V}_1 + \vec{V}_2 \]
Adding Vectors by Components

Adding vectors:

1. Draw a diagram; add the vectors graphically.
2. Choose $x$ and $y$ axes.
3. Resolve each vector into $x$ and $y$ components.
4. Calculate each component using sines and cosines.
5. Add the components in each direction.
6. To find the length and direction of the vector, you can use the Pythagorean Theorem;

$$V = \sqrt{V_x^2 + V_y^2}$$

$$\tan \theta = \frac{V_y}{V_x}$$