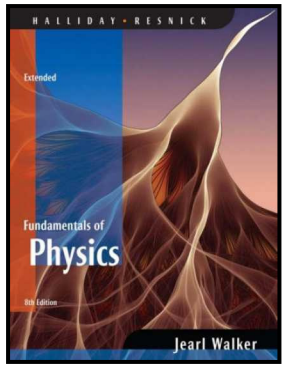
University Physics I



Week 1 : Day 2

The Art of Estimating

- **Weight of the air in Room**
  - The density of air is about 1.2 kg/m^3 in the room.
    - *Hint: Use the definition of density and estimate the volume.*

$$\rho = \frac{m}{V}$$

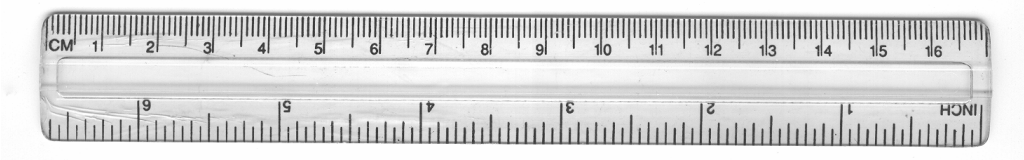
- **Mass of the Earth**
  - A nautical mile is by definition one minute of arc along the earth's surface, so 60 n mile = 1 ° and 1 n mile = 6076 feet = 1.15 mile
  - The density of water is 1 gram/cm^3 while the density of iron is 7.87 grams/cm^3.
    - *Hint: Use the arc length formula to find the radius of the Earth first and then use an average density.*

$$S = r\theta$$

Calculating Uncertainties

- **The uncertainty in a measured valued may be calculated in two ways:**
  - If a measurement is taken once use ½ of the smallest increment on the device.
    - *i.e., on a standard ruler use*

± ½mm = 0.5 mm =0.05 cm = 0.005 m



  - When a measurement is made more than once use the *standard deviation* as a measure of the uncertainty
    - *In general use the following:*

$$\Delta z = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(z_i - \bar{z})^2}, \quad \bar{z} \equiv \frac{1}{N}\sum_{i=1}^{N} z_i$$

Propagating Errors

- **Measurement errors compound in a derived quantity such as,**

$$z = x^m y^n$$

- **To determine the uncertainty in such a derived quantity use the following:**

$$\frac{\Delta z}{z} = |m|\frac{\Delta x}{x} + |n|\frac{\Delta y}{y}$$

Examples of Error Propogation

- **Error in a Rectangular Area**
  - Use the area formula

$$A = Lw \Rightarrow \frac{\Delta \mathrm{A}}{\mathrm{A}} = 1\frac{\Delta L}{L} + 1\frac{\Delta w}{w}$$

- **Error in the Volume of a Sphere**
  - Use the volume formula

$$V = \frac{4}{3}\pi r^3 \Rightarrow \frac{\Delta \mathrm{V}}{\mathrm{V}} = 3\frac{\Delta r}{r}$$

- **Error in Gravitational Force**
  - Use Newton's law of Universal Gravitation

$$F = G\frac{mM}{r^2} \Rightarrow \frac{\Delta \mathrm{F}}{F} = 1\frac{\Delta \mathrm{m}}{M} + 1\frac{\Delta \mathrm{M}}{M} + \left|-2\right|\frac{\Delta \mathrm{r}}{r}$$

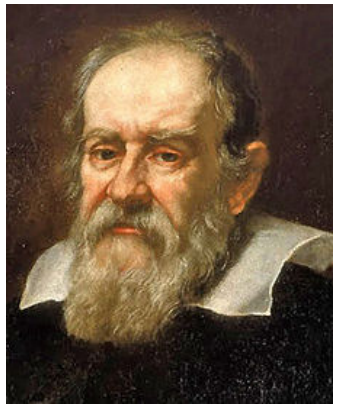
Problem – Density of a Mars Rock

- The mass of a particular (core) sample of rock retrieved from Mars is $m = 772.2 \pm 0.2$ g.
  - The sample is in the shape of a cylinder of height $h = 10 \pm 0.1$ cm and base radius $r = 2.5 \pm 0.1$ cm.
  - Calculate the density of the rock sample in kg/m^3.
  - State your result in the correct units with its associated uncertainty.

$\rho =$ _____ $\pm$ _____

Galileo and The Simple Pendulum

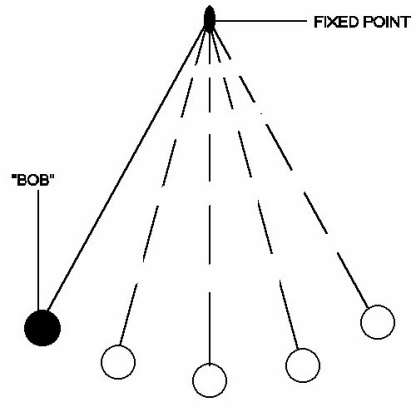
- **Galileo Galilei**
  - Viviani, Galileo's pupil,wrote that Galileo observed the motions of a chandelier hanging in a cathedral and noticed that it has a constant period even when moving at different angles.
  - Pendulums are mentioned in both Galileo's *Dialogue Concerning the Two Chief World Systems* and his *Dialogues Concerning Two New Sciences*. In these two works, Galileo discusses some of the major points he discovered about pendulums. Follow the links to jump to an experimental evaluation of the claim.
    1. *Pendulums nearly return to their release heights.*
    2. *All pendulums eventually come to rest with the lighter ones coming to rest faster.*
    3. *The period is independent of the bob weight.*
    4. *The period is independent of the amplitude.*
    5. *The square of the period varies directly with the length.*



Galileo Galilei
(1564 -1642)

- **Approximate Period**
  - If one ignores friction and use small angles of displacement the period is given by

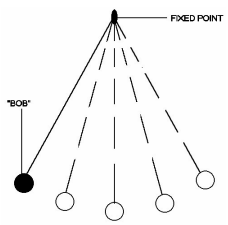
$$T = 2\pi\sqrt{\frac{L}{g}},\ \mathrm{g} = 9.8\,\frac{\mathrm{m}}{\mathrm{s}^2}$$



For more info see: http://galileo.rice.edu/lib/student_work/experiment95/galileo_pendulum.html

Activity – The Pendulum Period

- **Gather data for 5 different lengths**



  - Time 20 consecutive periods and divide by 20 to get the average period (T) for a given length (L)
    - *Keep the angle under 20°*
    - *Make a data table as shown*
  - Assign uncertainties to L and propagate error to determine ΔT
    - *For ΔL use half the smallest increment*
    - *How does average ΔT compare to average human reaction time of ~2/10 s?*
  - Make a graph of the period squared versus the length
    - *The graph should make a straight line.*
    - *What should this slope equal?*

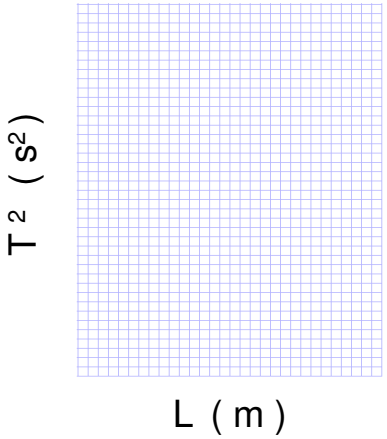
$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$\Downarrow$$

$$\frac{\Delta T}{T} = ?$$

Trial #	L (m)	T (s)	ΔT (s)
1			
2			
3			
4			
5			

Period Squared versus Length for a Simple Pendulum



Appendix C – Making a Good Graph

- **When making a graph include the following:**
  - Axis labels with units
  - All data points
    - *Outliers may be omitted*
  - Error bars
  - A meaningful title
  - For a straight line
    - *Trend line (equation)*
    - *Optionally include min, max and ave slopes*