Newtonian Mechanics

• Motion
  – of particles, animals, baseballs, rockets, planets galaxies, etc…

• Limitations
  – Good at all “practical scales”
  – Must use Quantum Mechanics at very small scales \( \Delta x \Delta p \sim \hbar \)
  – Must use Relativity at velocities nearing the speed of light and at high gravity
Chapter 1: Units and Measurement

• Physics involves measured quantities
  – What goes up must come down
  – But how high does it go?
• Measured Quantities
  – Must be expressed in units
  – Are always uncertain
Units

• Basic Units - Systeme Internationale (SI)
  – Length - Meter - (m)
  – Mass - Kilogram - (kg)
  – Time - Second - (s)

• Other Units
  – Length - mile, inch, yard, foot, kilometer,…
  – Mass - gram, milligram, microgram, slug,…
    • (a pound is a unit weight not a unit of mass)
  – Time - minute, hour, day, week, year,…
Metric Prefixes

femto  = 10^{-15} = f
pico   = 10^{-12} = p
nano   = 10^{-9} = n
micro  = 10^{-6} = \mu
milli  = 10^{-3} = m
centi  = 10^{-2} = c
deci   = 10^{-1} = d
deka   = 10^{1} = da
hecto  = 10^{2} = h
kilo   = 10^{3} = k
Mega   = 10^{6} = M
Giga   = 10^{9} = G
Tera   = 10^{12} = T
Peta   = 10^{15} = P

Examples

1 millimeter = 1 mm = 0.001 meter
1 kilogram = 1 kg = 1000 grams
1 centiliter = 1 cL = 0.01 Liters
1 Megawatt = 1 MW = 1,000,000 Watts
Units in Calculations

When multiplying and dividing, treat units like algebraic variables

\[(10\text{kg})(15\text{s})/(5\text{m} \times 10\text{m}) = (10\times15/(5\times10))(\text{kg} \times \text{s}/(\text{m} \times \text{m}))\]
\[= 3 \text{ kg-s/m}^2 = 3\text{kg} \cdot \text{s/m}^2\]

When adding and subtracting, units must be the same

\[10\text{m} + 5\text{s} = \text{undefined}\]

“Units are your friend”

speed \(= \sqrt{(10\text{m/s}^2)(4.9\text{m})}\)

\[= \sqrt{49\text{m}^2/\text{s}^2}\]

\[= 7.0 \text{ m/s}\]
Unit Conversions

$180 \text{ cm} = ? \text{ m}$

Conversion Factor: $1 \text{ cm} = 0.01 \text{ m}$

$0.01 \text{ m}/1 \text{ cm} = 1$

$180 \text{ cm} = 180 \text{ cm} \times (0.01 \text{ m}/1 \text{ cm}) = 1.80 \text{ m}$

$5.0 \text{ mg} = ? \text{ kg}$

Conversion Factors: $1 \text{ mg} = 0.001 \text{ g}$ \hspace{1cm} $1 \text{ kg} = 1000 \text{ g}$

$0.001 \text{ g}/1 \text{ mg} = 1$ \hspace{1cm} $1 \text{ kg}/1000 \text{ g} = 1$

$5.0 \text{ mg} = 5.0 \text{ mg} \times (0.001 \text{ g}/1 \text{ mg}) \times (1 \text{ kg}/1000 \text{ g})$

$= 0.0000050 \text{ kg} = 5.0 \times 10^{-6} \text{ kg}$
Unit Conversions

2.40 cm² = ? m²

Conversion Factor: \(0.01 \text{ m} / \text{1 cm} = 1\)

\[
2.40 \text{ cm}^2 = 2.40 \text{ cm}^2 \times \left(\frac{(0.01)^2 \text{ m}^2}{1 \text{ cm}^2}\right)
\]

\[
= 0.000240 \text{ m}^2 = 2.40 \times 10^{-4} \text{ m}^2
\]

65 mile/hour = ? m/s

Conversion Factor: \(1 = 1.61 \text{ km/mile}\) \(1 = 1000 \text{ m/km}\)
\(1 \text{ hour/60 min} = 1\) \(1 \text{ min/60 s} = 1\)

\[
65 \text{ mile/hour} \times \left(\frac{1.61 \text{ km/mile}}{1}\right) \times \left(\frac{1000 \text{ m/km}}{1}\right) \times \left(\frac{1 \text{ hour}}{60 \text{ min}}\right) \times \left(\frac{1 \text{ min}}{60 \text{ s}}\right)
\]

\[
= 29 \text{ m/s}
\]
Uncertainties

All measured quantities are uncertain.

The best way to indicate an uncertainty is with an uncertainty estimate:

\[ 8.5 \pm 0.3 \text{ cm} \quad \text{means between 8.2 and 8.8 cm} \]

In the lecture portion of this class we will use **significant figures**.

Usually, the last reported digit is a rough indication of uncertainty:

- 8.5  
  the 5 is uncertain  
  2 significant figures

- 8.54  
  the 4 is uncertain  
  3 significant figures

- 8.537  
  the 7 is uncertain  
  4 significant figures
**Significant Figures**

How many significant figures are there?

1. Count from the first non-zero digit on the left to the last non-zero digit on the left
   
   $0.00400200$ at least 4 significant figures

2. If there is a decimal point then the zeros on the right are counted
   
   $0.00400200$ 6 significant figures

3. If there is not a decimal point then the zeros on the right may or may not be counted
   
   $5000$ could be 1, 2, 3 or 4 significant figures

   * In Haliday, Resnick and Walker all zeros on the right are counted
   
   $5000$ is 4 significant figures

4. In scientific notation, all the digits to the left of the $10^x$ are significant
   
   $5 \times 10^3$ 1 significant figure
   
   $5.0 \times 10^3$ 2 significant figures
   
   $5.01 \times 10^3$ 3 significant figures
How many significant figures should there be reported in a result?

Direct Measurement

The number of significant figures is determined by measuring process.

Multiplication and Division

The number of significant figures is determined by the least precise of the factors and divisors (precision = number of significant figures)

The result should be rounded off to the same number of significant figures as the least precise factor or divisor

\[ \frac{2.000 \times 5.00}{15.00} = 0.667 \]

Should be rounded to 3 significant figures
Addition and Subtraction

The result should be rounded off according to the number whose smallest significant digit is largest

\[ 10.\overline{3} + 0.1\overline{7} = 10.5 \quad \text{Round off to the tenths place} \]

\[ 1,000,000.0 - 999,999.873 = 0.1 \quad \text{Round off to the tenths place} \]