Physics 1

Chapter 1 Measurement

1. Measurements and Units
   - Length
   - Time
   - Mass
2. Working with Numbers
3. How to Change Units

Review & Summary

Exercises & Problems

Measuring Things

- **Physics is based on experimental <u>measurement</u>.**

  - Quantitative measurements of each physical item are recorded by comparing the measured value to the result of measuring some **standard** amount of the physical item.
  - The **unit** is the name that is assigned to standard amount.
  - The exact definition of a unit is *arbitrary* but is chosen so that all scientists can use it to verify experimental results.
  - **Base standards** define the units for a few fundamental variables, in terms of which other physical quantities can be expressed.
    - e.g.: Speed in terms of length (miles) and time (hour).

Units of Measure

- In the physical world there are certain basic units:
  - Length
  - Mass
  - Time
  - Temperature
  - Electric Charge
  - Etc.

These are the basic units of the mechanical domain (Length, Mass, Time)

- From these we can define, or derive other units that we will discover as we proceed
  - Velocity (Length/Time)
  - Acceleration (Velocity/Time or L/T/T or L/T^2)
  - Force (Mass x Acceleration) or ML/T^2

The Mass Standard

Bureau International des Poids et Mesures, France

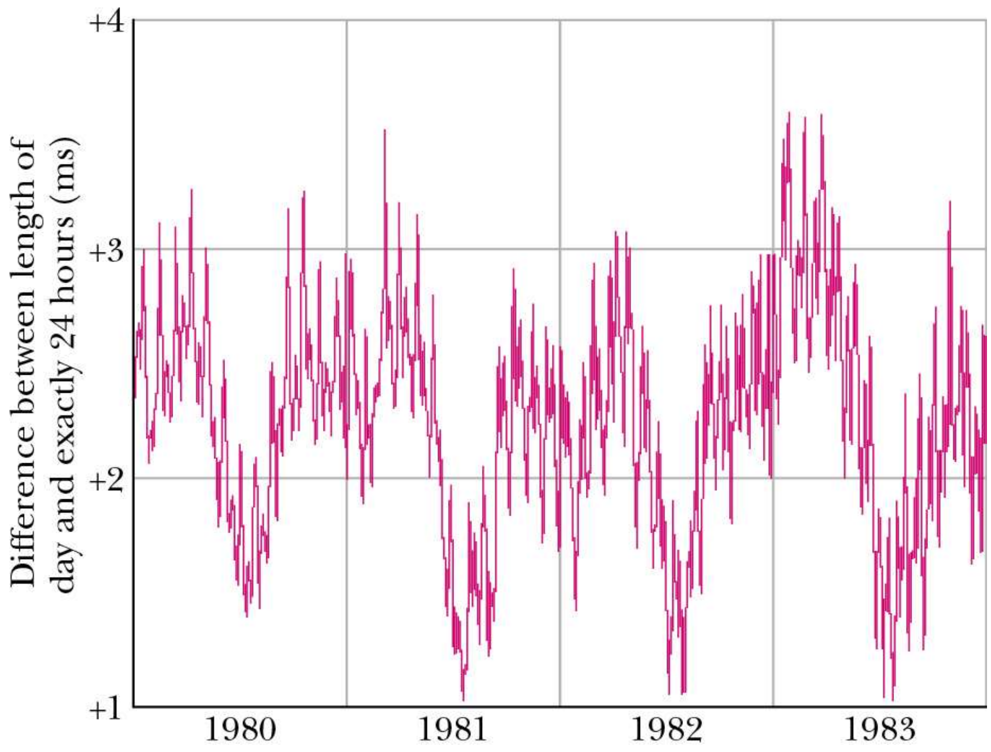
The SI standard of mass is a platinum–iridium cylinder kept at the International Bureau of Weights and Measures near Paris and assigned, by international agreement, a mass of 1 kilogram. Accurate copies have been sent to standardizing laboratories in other countries, and the masses of other bodies can be determined by balancing them against a copy.

Definition of One Second:

<u>Old Definition</u>: 86,400 seconds = 1 Day

But measurements reveal variations in the Length of an Earth Day!

86,400 seconds ≠ 1 day



Metric System (SI)

- The International System of Units
  - Length is measured in **Meters**
    - Originally defined as 1000m = 1/10,000 distance from the equator to the pole
    - Later defined in terms of a standard metal bar
    - Currently defined as distance light goes in vacuum in 1/299,792,458 seconds
  - Mass is measured in **Kilograms**
    - Originally the mass of 1000 cubic centimeters of water
    - Now a standard mass
  - Time is measure in **Seconds**
    - Originally 1/86,400 of one rotation of the earth
    - Now time for 9,192,631,770 wavelengths of cesium-133

Role of Units in Problem Solving

- Problems must be solved in a consistent set of units and you must be able to convert between different measures
  - Length: meters, inches, feet, yards, miles, rods, furlongs, hands, etc
  - Time: seconds, hours, days, weeks, months, years, fortnights, etc.
  - Mass: kilograms, stone
  - Force: newtons, ounces, pounds, tons, etc.
- How do you convert between units in a consistent way
  - Treat units like any other algebraic variable and multiply by a conversion factor:

    1 meter = 3.28 feet

    1 meter/3.28 feet = 1
  - Any variable multiplied by 1 does not change value, example:
    - Angel Falls, Venezuela is 979 meters tall
    - 979 m x (3.28 ft/m) = 3212 ft

Role of Units in Problem Solving

- Another example: 65 miles per hour in meters per second
  - Note that the word “per” is the same as division, e.g. 65 miles per hour is the same as 65miles/Hour
  - Using conversion factors in the book:

65 miles/hour x (5280 ft/mile) x 1 hour/3600 seconds = 95 ft/second

95 ft/second x (1 m/3.281ft) = 29 m/second

- Also provide useful checks
  - Just like algebraic quantities, only the same variable can be added or subtracted

Dimensional Analysis

- Dimension refers to the physical nature of the quantity and the type of unit used to specify it:

  Distance – dimension of Length

  Speed – Length per unit Time = Length/Time
- Many physical quantities can be described as a combination of the fundamental dimensions of Length, Mass, and Time
- Can use knowledge of dimensions to verify the correct form of an equation. Which of the following is dimensionally correct?

$X = ½ VT^2$ $\quad\quad$ L = [L/T]xTxT = LT

or

$X = ½ VT$ $\quad\quad$ L = [L/T]xT = L

The Representation of Measured Quantities!!!

- Significant Figures
  - The number of numerical figures recorded for a measured value reflects the measurement accuracy.
  - The final results of calculations are rounded to match the accuracy of the measurements that went into the calculation.
    - In multiplication and division, the answer should have the same number of significant figures as the least accurate of the quantities entering the calculation.
    - In addition and subtraction, the answer should have the same number of digits to the right of the decimal point as the term in the addition or subtraction that has the smallest number of digits to the right of the decimal point.

Conversions and Scientific Notation

- Prefixes for SI Units
  - see Appendix B of textbook
- Changing Units
  - Conversion factors are in Appendix D.
- Scientific Notation

Table 1.1

SI Prefixes

TABLE 1.1 SI Prefixes

Prefix	Symbol	Power
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}
deca	da	10^{1}
—	—	10^{0}
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}

Table 1.2

Scientific Notation

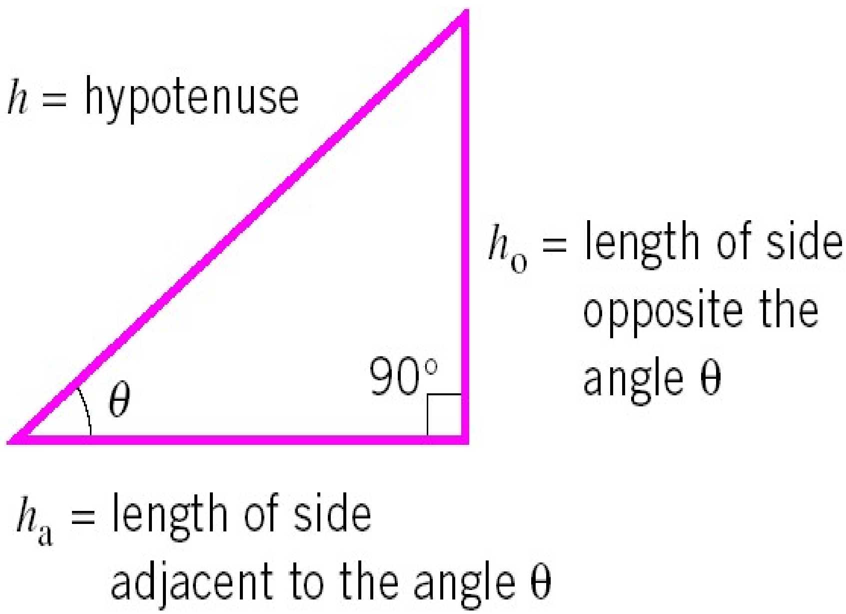
TABLE 1.2 Distances, Times, and Masses (rounded to one significant figure)

Radius of observable universe	1×10^{26} m
Earth's radius	6×10^{6} m
Tallest mountain	9×10^{3} m
Height of person	2 m
Diameter of red blood cell	1×10^{-5} m
Size of proton	1×10^{-15} m
Age of universe	4×10^{17} s
Earth's orbital period (1 year)	3×10^{7} s
Human heartbeat	1 s
Wave period, microwave oven	5×10^{-10} s
Time for light to cross a proton	3×10^{-24} s
Mass of Milky Way galaxy	1×10^{42} kg
Mass of mountain	1×10^{18} kg
Mass of human	70 kg
Mass of red blood cell	1×10^{-13} kg
Mass of uranium atom	4×10^{-25} kg
Mass of electron	1×10^{-30} kg

Mathematics

- Plotting and Graphing
- Algebra
- Trigonometry/Geometry
- Basic Calculus
  - Derivative
  - Integral
  - Partial Derivative
  - Differential Equation

Trigonometry



sin q = h_0/h

cos q = h_a/h

tan q = h_o/h_a

Note that these are numbers without units (ratios)

Inverse Trigometric Functions

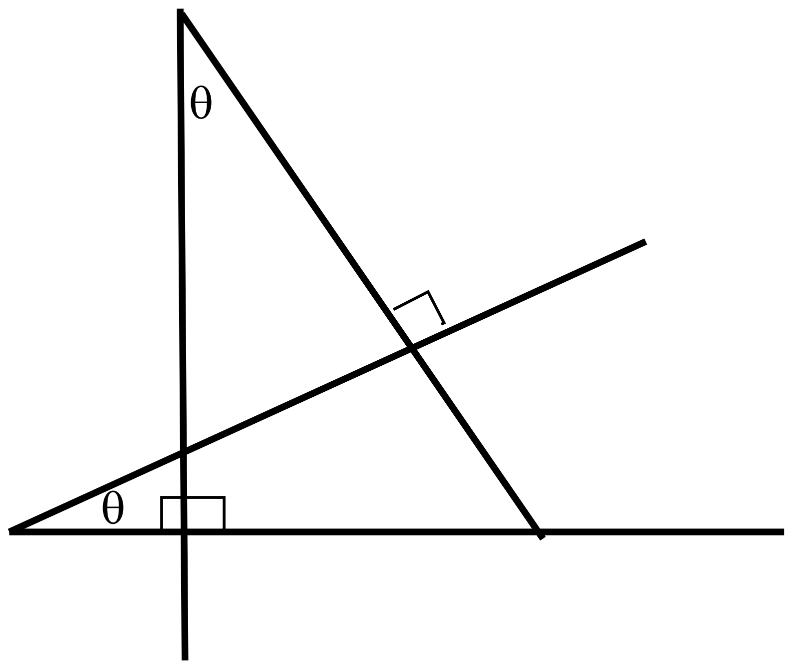
q = arcsin (h_o/h), sometimes written q = $\sin^{-1}$ (h_o/h)
= arccos (h_a/h)
= arctan (h_o/h_a)

- Note that if you have a right triangle and two of the four quantities (q, h, h_o, h_a) are known you always derive the other two

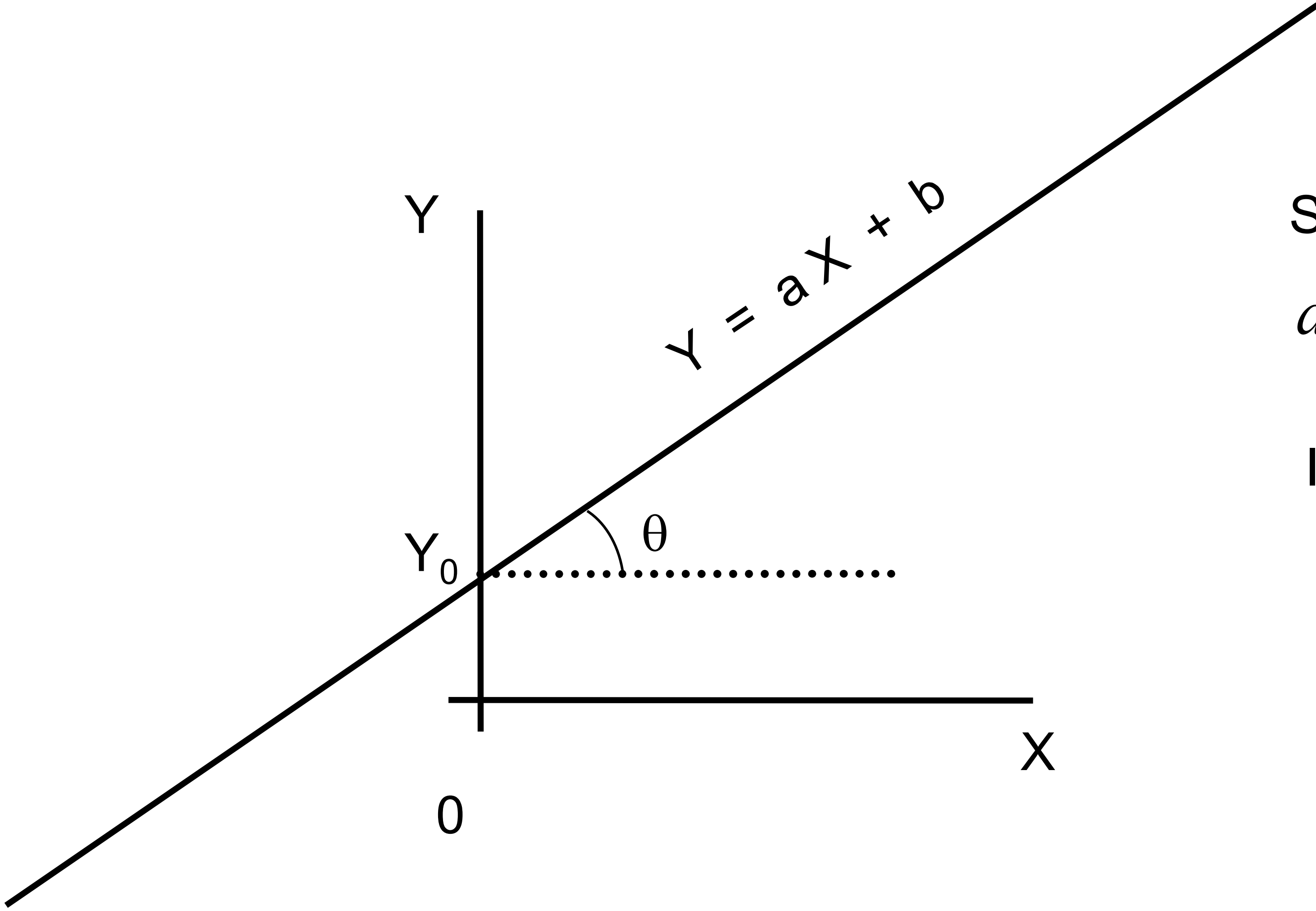
- Pythagorean equation for a right triangle

$$h^2 = (h_a)^2 + (h_o)^2$$

Congruent Angles



The Straight Line



Slope:

$$a = \tan\theta$$

Intercept:

$$b = Y_0$$

Quadratic Equation

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$