Physics for Scientists and Engineers

Introduction and Chapter 1 – Physics and Measurements

Quantities Used in Mechanics

- In mechanics, three fundamental quantities are used:
  - Length
  - Mass
  - Time
- All other quantities in mechanics can be expressed in terms of the three fundamental quantities.

Length

- Length is the distance between two points in space.
- Units
  - SI – meter, m
- Defined in terms of a meter – the distance traveled by light in a vacuum during a given time
- See Table 1.1 for some examples of lengths.

MASS

- Units
  - SI – kilogram, kg
- Defined in terms of a kilogram, based on a specific cylinder kept at the International Bureau of Standards
- See Table 1.2 for masses of various objects.

TIME

- Units
  - seconds, s
- Defined in terms of the oscillation of radiation from a cesium atom
- See Table 1.3 for some approximate time intervals.

Reasonableness of Results

- When solving a problem, you need to check your answer to see if it seems reasonable.
- Reviewing the tables of approximate values for length, mass, and time will help you test for reasonableness.

US Customary System

Still used in the US, but text will use SI

Quantity	Unit
Length	foot
Mass	slug
Time	second

Fundamental and Derived Units

- Derived quantities can be expressed as a mathematical combination of fundamental quantities.
- Examples:
  - Area
    - A product of two lengths
  - Speed
    - A ratio of a length to a time interval
  - Density
    - A ratio of mass to volume

Model Building

- A model is a system of physical components.
  - Useful when you cannot interact directly with the phenomenon
  - Identifies the physical components
  - Makes predictions about the behavior of the system
    - The predictions will be based on interactions among the components and/or
    - Based on the interactions between the components and the environment

Basic Quantities and Their Dimension

- Dimension has a specific meaning – it denotes the physical nature of a quantity.
- Dimensions are often denoted with square brackets.
  - Length [L]
  - Mass [M]
  - Time [T]

Dimensions and Units

- Each dimension can have many actual units.
- Table 1.5 for the dimensions and units of some derived quantities

TABLE 1.5 *Dimensions and Units of Four Derived Quantities*

Quantity	Area (A)	Volume (V)	Speed (v)	Acceleration (a)
Dimensions	L^2	L^3	L/T	L/T^2
SI units	m^2	m^3	m/s	m/s^2
U.S. customary units	ft^2	ft^3	ft/s	ft/s^2

Dimensional Analysis

- Technique to check the correctness of an equation or to assist in deriving an equation
- Dimensions (length, mass, time, combinations) can be treated as algebraic quantities.
  - Add, subtract, multiply, divide
- Both sides of equation must have the same dimensions.
- Any relationship can be correct only if the dimensions on both sides of the equation are the same.
- Cannot give numerical factors: this is its limitation

Dimensional Analysis, example

- Given the equation: $x = ½\, at^2$
- Check dimensions on each side:

$$L = \frac{L}{\cancel{T^2}} \cdot \cancel{T^2} = L$$

- The T^2's cancel, leaving L for the dimensions of each side.
  - The equation is dimensionally correct.
  - There are no dimensions for the constant.

Dimensional Analysis to Determine a Power Law

- Determine powers in a proportionality
  - Example: find the exponents in the expression

$$x \propto a^m t^n$$

  - You must have lengths on both sides.
  - Acceleration has dimensions of L/T^2
  - Time has dimensions of T.
  - Analysis gives

$$x \propto at^2$$

Symbols

- The symbol used in an equation is not necessarily the symbol used for its dimension.
- Some quantities have one symbol used consistently.
  - For example, time is *t* virtually all the time.
- Some quantities have many symbols used, depending upon the specific situation.
  - For example, lengths may be x, y, z, r, d, h, etc.
- The dimensions will be given with a capitalized, non-italic letter.
- The algebraic symbol will be italicized.

Conversion of Units

- When units are not consistent, you may need to convert to appropriate ones.
- See Appendix A for an extensive list of conversion factors.
- Units can be treated like algebraic quantities that can cancel each other out.

Conversion

- Always include units for every quantity, you can carry the units through the entire calculation.
  - Will help detect possible errors
- Multiply original value by a ratio equal to one.
- Example:

$$15.0\,in = ?\,cm$$

$$15.0\,\cancel{in}\left(\frac{2.54\,cm}{1\,\cancel{in}}\right) = 38.1\,cm$$

  - Note the value inside the parentheses is equal to 1, since 1 inch is defined as 2.54 cm.