Chapter 1

Physics and Measurements

Physics

Fundamental Science

- Concerned with the fundamental principles of the Universe
- Foundation of other physical sciences
- Has simplicity of fundamental concepts

Physics, cont.

Divided into six major areas:

- *Classical Mechanics*
- *Relativity*
- *Thermodynamics*
- *Electromagnetism*
- *Optics*
- *Quantum Mechanics*

Classical Physics

Mechanics and electromagnetism are basic to all other branches of classical and modern physics.

Classical physics

- Developed before 1900
- First part of text deals with Classical Mechanics
  - Also called Newtonian Mechanics or Mechanics

Modern physics

- From about 1900 to the present

Objectives of Physics

To find the limited number of fundamental laws that govern natural phenomena

To use these laws to develop theories that can predict the results of future experiments

Express the laws in the language of mathematics

- Mathematics provides the BRİDGE between theory and experiment.

Theory and Experiments

Should complement each other

When a discrepancy occurs, theory may be modified or new theories formulated.

- A theory may apply to limited conditions.
  - Example: Newtonian Mechanics is confined to objects traveling slowly with respect to the speed of light.
- Try to develop a more general theory

Classical Physics Overview

Classical physics includes principles in many branches developed before 1900.

Mechanics

- Major developments by NEWTON, and *continuing through* the 18th century

Thermodynamics, optics and electromagnetism

- Developed in the latter part of the 19th century
- Apparatus for controlled experiments became available

Modern Physics

Began near the end of the 19th century

Phenomena that could not be explained by classical physics

Includes theories of relativity and quantum mechanics

Special Relativity

Correctly describes motion of objects moving near the speed of light

Modifies the traditional concepts of space, time, and energy

Shows the speed of light is the upper limit for the speed of an object

Shows mass and energy are related

Quantum Mechanics

Formulated to describe physical phenomena at the atomic level

Led to the development of many practical devices

Measurements

Used to describe natural phenomena

Each measurement is associated with a physical quantity

Need defined standards

Characteristics of standards for measurements

- Readily accessible
- Possess some property that can be measured reliably
- Must yield the same results when used by anyone anywhere
- Cannot change with time

Standards of Fundamental Quantities

Standardized systems

- Agreed upon by some authority, usually a governmental body

SI – Systéme International

- Agreed to in 1960 by an international committee
- Main system used in this text

Fundamental Quantities and Their Units

Quantity	SI Unit
Length	meter
Mass	kilogram
Time	second
Temperature	Kelvin
Electric Current	Ampere
Luminous Intensity	Candela
Amount of Substance	mole

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

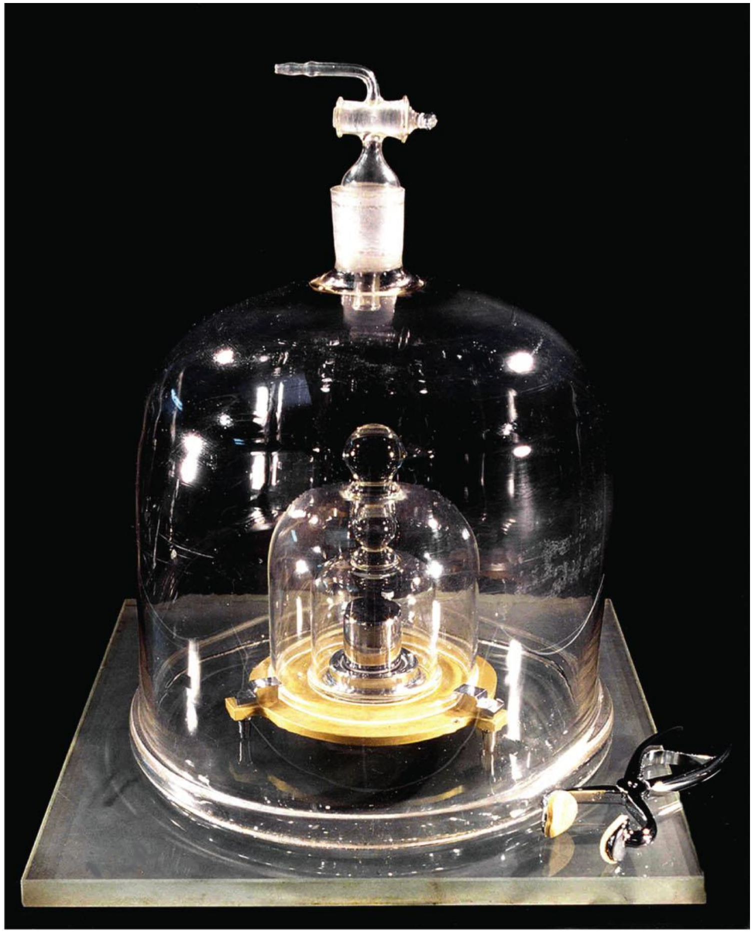
Mass

Units

- **SI – kilogram, kg**

Defined in terms of a kilogram, based on a specific cylinder kept at the International Bureau of Standards

Standard Kilogram



a

Time

Units

- seconds, s

Defined in terms of the oscillation of radiation from a cesium atom

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.

Number Notation

When writing out numbers with many digits, spacing in groups of three will be used.

- No commas
- Standard international notation

Examples:

- 25 100
- 5.123 456 789 12

US Customary System

Still used in the US, but text will use SI

Quantity	Unit
Length	foot
Mass	slug
Time	second

Prefixes

Prefixes correspond to powers of 10.

Each prefix has a **specific name.**

Each prefix has a **specific abbreviation.**

The prefixes can be used with **any basic units.**

They are multipliers of the basic unit.

Examples:

- 1 mm = 10^{-3} m
- 1 mg = 10^{-3} g

Prefixes, cont.

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-24}	yocto	y	10^{3}	kilo	k
10^{-21}	zepto	z	10^{6}	mega	M
10^{-18}	atto	a	10^{9}	giga	G
10^{-15}	femto	f	10^{12}	tera	T
10^{-12}	pico	p	10^{15}	peta	P
10^{-9}	nano	n	10^{18}	exa	E
10^{-6}	micro	μ	10^{21}	zetta	Z
10^{-3}	milli	m	10^{24}	yotta	Y
10^{-2}	centi	c			
10^{-1}	deci	d			

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

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 show the dimensions and units of some 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: $x = \frac{1}{2} at^2$

Check dimensions on each side:

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

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.

Order of Magnitude

Approximation based on a number of assumptions

- May need to modify assumptions if more precise results are needed

The order of magnitude is the power of 10 that applies.

Order of Magnitude – Process

Estimate a number and express it in scientific notation.

- The multiplier of the power of 10 needs to be between 1 and 10.

Compare the multiplier to 3.162 ($\sqrt{10}$)

- If the remainder is less than 3.162, the order of magnitude is the power of 10 in the scientific notation.
- If the remainder is greater than 3.162, the order of magnitude is one more than the power of 10 in the scientific notation.

Using Order of Magnitude

Estimating too high for one number is often canceled by estimating too low for another number.

- The resulting order of magnitude is generally reliable within about a factor of 10.

Working the problem allows you to drop digits, make reasonable approximations and simplify approximations.

With practice, your results will become better and better.

Uncertainty in Measurements

There is uncertainty in every measurement – this uncertainty carries over through the calculations.

- May be due to the apparatus, the experimenter, and/or the number of measurements made
- Need a technique to account for this uncertainty

We will use rules for significant figures to approximate the uncertainty in results of calculations.

Significant Figures

A significant figure is one that is reliably known.

Zeros may or may not be significant.

- Those used to position the decimal point are not significant.
- To remove ambiguity, use scientific notation.

In a measurement, the significant figures include the first estimated digit.

Significant Figures, examples

0.0075 m has 2 significant figures

- The leading zeros are placeholders only.
- Write the value in scientific notation to show more clearly:

  7.5×10^{-3} m for 2 significant figures

10.0 m has 3 significant figures

- The decimal point gives information about the reliability of the measurement.

1500 m is ambiguous

- Use 1.5×10^{3} m for 2 significant figures
- Use 1.50×10^{3} m for 3 significant figures
- Use 1.500×10^{3} m for 4 significant figures

Operations with Significant Figures – Multiplying or Dividing

When multiplying or dividing several quantities, the number of significant figures in the final answer is the same as the number of significant figures in the quantity having the smallest number of significant figures.

Example: 25.57 m x 2.45 m = 62.6 m^2

- The 2.45 m limits your result to 3 significant figures.

Operations with Significant Figures – Adding or Subtracting

When adding or subtracting, the number of decimal places in the result should equal the smallest number of decimal places in any term in the sum or difference.

Example: 135 cm + 3.25 cm = 138 cm

- The 135 cm limits your answer to the units decimal value.

Operations With Significant Figures – Summary

The rule for addition and subtraction are different than the rule for multiplication and division.

For adding and subtracting, the ***number of decimal places*** is the important consideration.

For multiplying and dividing, the ***number of significant figures*** is the important consideration.

Significant Figures in the Text

Most of the numerical examples and end-of-chapter problems will yield answers having three significant figures.

When estimating a calculation, typically work with one significant figure.