Physics for Scientists and Engineers

Introduction

and

Chapter 1

Physics

- Fundamental Science
  - concerned with the basic principles of the Universe
  - foundation of other physical sciences
- Divided into five major areas
  - Classical Mechanics
  - Relativity
  - Thermodynamics
  - Electromagnetism
  - Optics
  - Quantum Mechanics

Classical Physics

- Mechanics and electromagnetism are basic to all other branches of classical physics
- Classical physics developed before 1900
  - Our study will start with Classical Mechanics
    - Also called Newtonian Mechanics

Classical Physics, cont

- Includes Mechanics
  - Major developments by Newton, and continuing through the latter part of the 19^{th} century
- Thermodynamics
- Optics
- Electromagnetism
  - All of these were not developed until the latter part of the 19^{th} century

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

Classical Mechanics Today

- Still important in many disciplines
- Wide range of phenomena that can be explained with classical mechanics
- Many basic principles carry over into other phenomena
- Conservation Laws also apply directly to other areas

Objective 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

Theory and Experiments

- Should complement each other
- When a discrepancy occurs, theory may be modified
  - Theory may apply to limited conditions
    - Example: Newtonian Mechanics is confined to objects traveling slowing with respect to the speed of light
  - Try to develop a more general theory

Quantities Used

- In mechanics, three *basic quantities* are used
  - Length
  - Mass
  - Time
- Will also use *derived quantities*
  - These are other quantities can be expressed in terms of these

Standards of 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

Length

- 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

Standard Kilogram

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

Number Notation

- When writing out numbers with many digits, spacing in groups of three will be used
  - No commas
- Examples:
  - 25 100
  - 5.123 456 789 12

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

Systems of Measurements, cont

- US Customary
  - everyday units
  - Length is measured in feet
  - Time is measured in seconds
  - Mass is measured in slugs
    - often uses weight, in pounds, instead of mass as a fundamental quantity

Prefixes

- Prefixes correspond to powers of 10
- Each prefix has a specific name
- Each prefix has a specific abbreviation

Prefixes, cont.

- The prefixes can be used with any base units
- They are multipliers of the base unit
- Examples:
  - 1 mm = 10^{-3} m
  - 1 mg = 10^{-3} g

Table 1.4

Prefixes for Powers of Ten

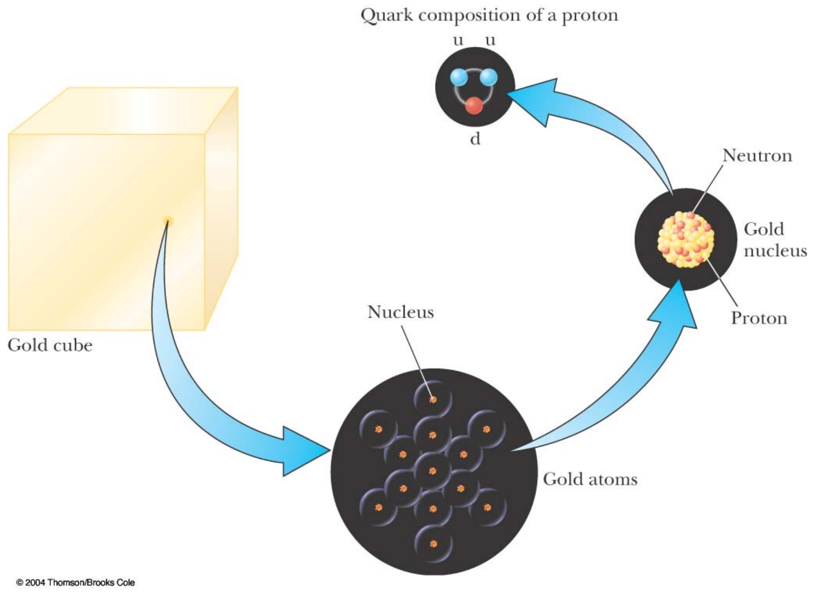
Power	Prefix	Abbreviation
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z
10^{24}	yotta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

Model Building

- A ***model*** is a system of physical components
  - Identify the components
  - Make 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

Models of Matter

- Some Greeks thought matter is made of atoms
- JJ Thomson (1897) found electrons and showed atoms had structure
- Rutherford (1911) central nucleus surrounded by electrons



Models of Matter, cont

- Nucleus has structure, containing protons and neutrons
  - Number of protons gives atomic number
  - Number of protons and neutrons gives mass number
- Protons and neutrons are made up of quarks

Modeling Technique

- Important technique is to build a model for a problem
  - Identify a system of physical components for the problem
  - Make predictions of the behavior of the system based on the interactions among the components and/or the components and the environment

Density

- Density is an example of a ***derived*** quantity
- It is defined as mass per unit volume

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

- Units are kg/m^3
- See table 1.5 for some density values

Atomic Mass

- The atomic mass is the total number of protons and neutrons in the element
- Can be measured in ***atomic mass units***, u
  - 1 u = $1.6605387 \times 10^{-27}$ kg

Basic Quantities and Their Dimension

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

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

Dimensional Analysis, cont.

- Cannot give numerical factors: this is its limitation
- Dimensions of some common quantities are given below

Table 1.6

Units of Area, Volume, Velocity, Speed, and Acceleration

System	Area (L^2)	Volume (L^3)	Speed (L/T)	Acceleration (L/T^2)
SI	m^2	m^3	m/s	m/s^2
U.S. customary	ft^2	ft^3	ft/s	ft/s^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.

Dimensional Analysis, example

- Given the equation: $x = \frac{1}{2} at^2$
- Check dimensions on each side:

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

- 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

Conversion of Units

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

Conversion

- Always include units for every quantity, you can carry the units through the entire calculation
- Multiply original value by a ratio equal to one
- Example $15.0\,\text{in} = ?\,\text{cm}$

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

Order of Magnitude

- Approximation based on a number of assumptions
  - may need to modify assumptions if more precise results are needed
- Order of magnitude is the power of 10 that applies

Uncertainty in Measurements

- There is uncertainty in every measurement -- this uncertainty carries over through the calculations
  - 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
  - Can write 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, the number of significant figures in the final answer is the same as the number of significant figures in the quantity having the lowest 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.
- 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

Rounding

- Last retained digit is increased by 1 if the last digit dropped is 5 or above
- Last retained digit remains as it is if the last digit dropped is less than 5
- If the last digit dropped is equal to 5, the retained digit should be rounded to the nearest even number
- Saving rounding until the final result will help eliminate accumulation of errors