1.15: Units and Measurement (Summary)

Key Terms

accuracy	the degree to which a measured value agrees with an accepted reference value for that measurement
base quantity	physical quantity chosen by convention and practical considerations such that all other physical quantities can be expressed as algebraic combinations of them
base unit	standard for expressing the measurement of a base quantity within a particular system of units; defined by a particular procedure used to measure the corresponding base quantity
conversion factor	a ratio that expresses how many of one unit are equal to another unit
derived quantity	physical quantity defined using algebraic combinations of base quantities
derived units	units that can be calculated using algebraic combinations of the fundamental units
dimension	expression of the dependence of a physical quantity on the base quantities as a product of powers of symbols representing the base quantities; in general, the dimension of a quantity has the form $L^a M^b T^c I^d \Theta^e N^f J^g$ for some powers a, b, c, d, e, f, and g
dimensionally consistent	equation in which every term has the same dimensions and the arguments of any mathematical functions appearing in the equation are dimensionless
dimensionless	quantity with a dimension of $L^0 M^0 T^0 I^0 \Theta^e N^0 J^0 = 1$; also called quantity of dimension 1 or a pure number
discrepancy	the difference between the measured value and a given standard or expected value
English units	system of measurement used in the United States; includes units of measure such as feet, gallons, and pounds
estimation	using prior experience and sound physical reasoning to arrive at a rough idea of a quantity's value; sometimes called an "order-of-magnitude approximation," a "guesstimate," a "back-of-the-envelope calculation", or a "Fermi calculation"
kilogram	SI unit for mass, abbreviated kg
law	description, using concise language or a mathematical formula, of a generalized pattern in nature supported by scientific evidence and repeated experiments
meter	SI unit for length, abbreviated m
method of adding percents	the percent uncertainty in a quantity calculated by multiplication or division is the sum of the percent uncertainties in the items used to make the calculation
metric system	system in which values can be calculated in factors of 10
model	representation of something often too difficult (or impossible) to display directly

order of magnitude	the size of a quantity as it relates to a power of 10
percent uncertainty	the ratio of the uncertainty of a measurement to the measured value, expressed as a percentage
physical quantity	characteristic or property of an object that can be measured or calculated from other measurements
physics	science concerned with describing the interactions of energy, matter, space, and time; especially interested in what fundamental mechanisms underlie every phenomenon
precision	the degree to which repeated measurements agree with each other
second	the SI unit for time, abbreviated s
SI units	the international system of units that scientists in most countries have agreed to use; includes units such as meters, liters, and grams
significant figures	used to express the precision of a measuring tool used to measure a value
theory	testable explanation for patterns in nature supported by scientific evidence and verified multiple times by various groups of researchers
uncertainty	a quantitative measure of how much measured values deviate from one another
units	standards used for expressing and comparing measurements

Key Equations

Percent uncertainty	$$Percent\ uncertainty = \frac{\delta A}{A} \times 100\% \tag{1.15.1}$$

Summary

1.1 The Scope and Scale of Physics

- Physics is about trying to find the simple laws that describe all natural phenomena.
- Physics operates on a vast range of scales of length, mass, and time. Scientists use the concept of the order of magnitude of a number to track which phenomena occur on which scales. They also use orders of magnitude to compare the various scales.
- Scientists attempt to describe the world by formulating models, theories, and laws

1.2 Units and Standards

- Systems of units are built up from a small number of base units, which are defined by accurate and precise measurements of conventionally chosen base quantities. Other units are then derived as algebraic combinations of the base units.
- Two commonly used systems of units are English units and SI units. All scientists and most of the other people in the world use SI, whereas nonscientists in the United States still tend to use English units.
- The SI base units of length, mass, and time are the meter (m), kilogram (kg), and second (s), respectively.
- SI units are a metric system of units, meaning values can be calculated by factors of 10. Metric prefixes may be used with metric units to scale the base units to sizes appropriate for almost any application.

1.3 Unit Conversion

- To convert a quantity from one unit to another, multiply by conversion factors in such a way that you cancel the units you want to get rid of and introduce the units you want to end up with.
- Be careful with areas and volumes. Units obey the rules of algebra so, for example, if a unit is squared we need two factors to cancel it.

1.4 Dimensional Analysis

- The dimension of a physical quantity is just an expression of the base quantities from which it is derived.
- All equations expressing physical laws or principles must be dimensionally consistent. This fact can be used as an aid in remembering physical laws, as a way to check whether claimed relationships between physical quantities are possible, and even to derive new physical laws.

1.5 Estimates and Fermi Calculations

- An estimate is a rough educated guess at the value of a physical quantity based on prior experience and sound physical reasoning. Some strategies that may help when making an estimate are as follows:
  - Get big lengths from smaller lengths.
  - Get areas and volumes from lengths.
  - Get masses from volumes and densities.
  - If all else fails, bound it. One "sig. fig." is fine.
  - Ask yourself: Does this make any sense?

1.6 Significant Figures

- Accuracy of a measured value refers to how close a measurement is to an accepted reference value. The discrepancy in a measurement is the amount by which the measurement result differs from this value.
- Precision of measured values refers to how close the agreement is between repeated measurements. The uncertainty of a measurement is a quantification of this.
- The precision of a measuring tool is related to the size of its measurement increments. The smaller the measurement increment, the more precise the tool.
- Significant figures express the precision of a measuring tool.
- When multiplying or dividing measured values, the final answer can contain only as many significant figures as the least-precise value.
- When adding or subtracting measured values, the final answer cannot contain more decimal places than the least-precise value.

1.7 Solving Problems in Physics

The three stages of the process for solving physics problems used in this textmap are as follows:

- **Strategy**: Determine which physical principles are involved and develop a strategy for using them to solve the problem.
- **Solution**: Do the math necessary to obtain a numerical solution complete with units.
- **Significance**: Check the solution to make sure it makes sense (correct units, reasonable magnitude and sign) and assess its significance.

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