

I. Measurement

In order to completely describe a physical quantity, we usually must supply both a _____ and _____.

Examples:

John weighs _____

The height of a basketball goal is _____

The magnitude of the force of gravity on the ball was _____

The temperature is _____

Caution: People often assume that the units of a measurement are understood!!! This is unacceptable for a scientist or engineer since failure to communicate units can cause PHYSICAL as well as ECONOMICAL harm to people.

EX: A micorampmere of current is harmless while a ampere of current is potentially fatal!!

II. Units

A. System International (SI)

Scientists almost always work in the System International (SI) unit system. This system is based upon the base 10 and has many advantages over the English system of units. For instance, American car and other English system manufactures are at a disadvantage when machining precision parts including engines due to the superior precision of the SI based machining tools. Furthermore, in electronics there is only the SI system. Thus, we will use the SI system throughout this course. However, because scientists and engineers must deal with individuals who are either use other unit systems or are unfamiliar with the SI system, you may learn additional unit systems in your specialty classes.

B. Fundamental Units

1. Length

The fundamental unit of length in the SI system is the _____.

2. Time

The fundamental unit of time in the SI system is the _____.

3. Inertia

The fundamental unit of inertia in the SI system is the _____.

4. Current

The fundamental unit of current in the SI system is the _____.

5. Other Units

There are several other fundamental units that will be defined in other physics course.

C. Derived Units

Most of the units in physics and engineering are derived units (combinations of the fundamental units).

EXAMPLES:

unit of force _____

unit of energy _____

unit of acceleration _____

D. Algebra of Units and Dimensional Analysis

Units obey the same algebra rules that variables obey in algebra class!!

EXAMPLE: If **x** has the units of meters and **t** has the units of seconds then if **a** obeys the following equation

$$x = \frac{1}{2} a t^2$$

then we can find the units for **a** as follows:

E. Dimensional Analysis

We can use units algebra (dimensional analysis) to help us check our math work and to determine if a particular formula is correct!

UNITS are your FRIENDS!!

You should check the units on every line of your work. **I will be checking and grading them! This is how I find your mistakes and give you partial credit!!**

Rule 1: The units on both sides of an algebraic equation must be the same!

Example: If **x** is distance in meters, **t** is time in seconds, and **v** is speed in meters/seconds, is the following formula dimensionally correct?

$$V = x t$$

Rule 2: The units for each term of an algebraic equation must be the same!

Example: Assuming that x_0 , x , t , v_0 , and a have the units of meters, meters, seconds, meters/second, and meters/second² respectively, is the following equation dimensionally correct?

$$x = x_0 + v_0 t + a t^3$$

Rule 3: The **arguments** of all **trigonometric** and **exponential functions** MUST be **unitless**!

Explanation: Trigonometric and exponential functions can be expressed in terms of power series. Each term of the series must have the same units according to Rule 2. As an example, we consider the series representation of the cosine function:

$$\cos(x) = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

If x had units (meters for instance) then the equation would be dimensionally incorrect. Thus, we see that x must be unitless!!!

Example: If the decay of a radioactive nucleus is described by the following equation, what are the units of τ ?

$$N = N_0 e^{-t/\tau}$$

F. SI Prefixes

It is important for scientists and engineers to be able to quickly make **rough calculations** to determine if their designs are **practicable** and **safe**. A detailed calculation may take months and shouldn't be attempted if the design has no chance of success.

Humans do not work well with large or small numbers. When numerical values become too large or small, our math intuition begins to fail us. Thus, we are more prone to mistakes and less likely to accurately interpret data. Unfortunately, the universe requires us to work with numbers that differ by over forty orders of magnitude.

We solve this dilemma through the use of prefixes and engineering notation. In this way, we can restrict our numbers to values between 0.1 and 999.9

Example: Write the following number using scientific notation and the correct number of significant figures and units.

325,500 meters

Example: Write the following number using scientific notation and the correct number of significant figures and units.

0.3250 meters

Example: Write the following number using engineering notation (exponent must be a multiple of three) and the correct number of significant figures and units.

325,500 meters

Prefixes:

Amount	Prefix	Symbol	Amount	Prefix	Symbol
10^{12}			10^{-3}		
10^9			10^{-6}		
10^6			10^{-9}		
10^3			10^{-12}		
10^0			10^{-15}		

Problem: For each of the following measurements, list a possible object that the measurement might describe.

a. 123,000 meters

b. 0.0000457 meters

c. 0.0000762 kilograms

Example: Use engineering notation and unit prefixes to simplify the following physical quantities:

a. 123,000 meters

b. 0.0000457 meters

c. 0.0000762 kilograms

Question: Using your new results, check to see if the objects that you chose in the previous problem are reasonable. If an object is not reasonable, list a new item for the measurement.

2. Using Units To Make Quick Calculations

A good understanding of the use of units is essential for all scientists and engineers!!

Example: A 30 micro-ampere current flows through a 22.7 kilo-ohm resistor in a circuit. Is it dangerous to place your hands across the resistor?

Solution:

According to ohm's law which will be covered in the next course, the voltage, V , across a resistor is related to the current, I , through a resistor of resistance, R , by the equation: $V = I R$

The resulting voltage is approximately

$$V = (30 \text{ micro-amperes})(20 \text{ kilo-ohms}) = 600 \text{ millivolts!!!}$$

This is less than the voltage across a watch battery that you can purchase at Walmart and is safe.

III. Fermi Calculations:

It is often useful for technical people to be able to make quick order of magnitude calculations to see if a particular solution is possible or to determine if particular data requires more careful checking. These order of magnitude calculations are called Fermi calculations after the great physicist Enrico Fermi.

Example 1: Roughly how tall is the empire state building (10ft, 100 ft, 1000 ft, 10,000 ft, etc)?

Example 2: You are told that there were 960 home runs last year in the majors. Is this number reasonable?

ASIDE:

The outcome of human history has actually been altered when an individual has failed to make these simple calculations.

Example: During the American Civil War, Union General McClellan acted upon information by Allan Pinkerton his chief of intelligence and delayed attacking the confederate army at Yorktown. From horse traffic, observations of pickets and using his own mathematical formula, Pinkerton estimated a confederate army of almost 200,000 men. **Why is this calculation not sensible?**

Answer:

Because McClellan already knew the following:

1) A large confederate army was at Manassas, Va (It had defeated the previous Union commander). - It had at least 100,000 men according to McClellan which is why he ferried his army down to the Virginia peninsula.

2) In addition to confederate units in Arkansas, Missouri, Louisiana, and Texas, three other major confederate armies existed:

- an army working in Mississippi and Tennessee of 60,000-100,000 men
- an army working in the Shennandoah Valley of 30,00-60,000 men

If we total all of these armies, we get a rough estimate of 400,000 men. The South had a much smaller population than the North. Even with a liberal estimate of 5,000,000 available men, the southern armies would represent 8% of all the men in the country. Given that the South didn't even have an army at the beginning of the war, it is unlikely that they could have raised and trained such a large amount of men in less than one year. Thus, the calculation for at least one of the two large Virginia armies was probably inaccurate. Since no contact had been made with the army at Yorktown, its calculation should have been checked.

Actual Number: McClellan and his 100,000 men faced an army of less than 30,000 men and could have ended the war saving more than a million deaths. Instead, he never questioned the numbers presented to him or how they were obtained. He set up a siege operation and giving the confederates time to fall back and bring up reinforcements from Manassas to fight him. McClellan was a gifted railroad engineer and in many ways a brilliant general, but he failure to handle numbers prevented him on several occasions from

defeating the South. Had he properly handled intelligence, he might have eventually become president and certainly U.S. Grant would never have achieved fame and the presidency. Instead U.S. Grant whose favorite subject at West Point was math and who Lincoln said “was able to do the terrible math” eventually rose to lead the Union army to victory.

This is only one of many examples in human history but it does point out one difference between homework and real world problems. In the real world, it is difficult or even impossible sometimes to obtain actual numerical data. Thus decisions must be made on imperfect information. Skill in making use of approximations and models are essential.