Measuring Time, Space, and Matter

Physics is an experimental science. To understand physics we must be able to connect our theoretical description of nature with our experimental observations of nature. This connection is made through quantitative measurements. To that end, we require some understanding of measurements and how they are made.

Units of Measurement

In physics, we use several **fundamental characteristics** to describe nature. We also use certain **fundamental units** to quantify each characteristic. These characteristics, along with the appropriate units, are listed on the table below.

SI Fundamental Units			
Physical Quantity	**Quantity Symbol**	**Unit of Measure**	**Unit Symbol**
length	l	meter	m
mass	m	kilogram	kg
time	t	second	s
charge	Q	Coulomb	C

Physical Quantity – any measurable aspect of the universe.

A wide variety of other units, called **derived units**, are combinations of the base units. For example, speed is a measure of how far an object travels (meters) in a given amount of time (seconds). We measure speed in meters per second (m/s), a derived unit. Some other common derived units:

SI Derived Units				
Quantity	**Unit**	**Symbol**	**In Base Units**	**Alternate Units**
Acceleration		m/s^2	m/s^2	
Electric Charge	Coulomb	C	$A \cdot s$	
Electric Field		N/C	$kg \cdot m/C \cdot s^2$	
Force	Newton	N	$kg \cdot m/s^2$	
Frequency	Hertz	Hz	s^{-1}	
Magnetic Field	Tesla	T	$kg/A \cdot s^2$	
Momentum, Impulse		$kg \cdot m/s$	$kg \cdot m/s$	$N \cdot s$
Velocity		m/s	m/s	

In physics, we often encounter numbers that are either very large or very small. These numbers can be most easily expressed in one of two ways:

1. **Scientific Notation**

Numbers in scientific notation have the form:

$$M \times 10^n$$

where **M** is a number having a single nonzero figure to the left of the decimal point and **n** is a positive or negative exponent.

To write a number in scientific notation:

- Determine **M** by shifting the decimal point in the original number to the left or to the right until only one nonzero digit is to the left of it. **M** should contain only the significant figures of the original number.

- Determine **n** by counting the number of places the decimal has been shifted; if it has been moved to the left, **n** is positive; if to the right, **n** is negative.

e.g. Speed of Light = 3.00×10^8 m/s

2. Metric Prefixes

Using scientific notation, 1670 meters can be written as 1.67×10^3 meters. But this same quantity can also be written 1.67 kilometers – abbreviated as 1.67 km. This is an example of using a prefix to indicate a multiple of a base unit. Here the prefix kilo means one thousand or 10^3. The following table gives the prefixes for other common multiples of units:

Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

When using numbers with prefixes, they should be converted to scientific notation in the proper units before being used in calculations.

Unit Conversions

It is often necessary to change from one set of units to another. For example, you may have to convert a given number of seconds into minutes, or a given number of centimeters into meters.

The procedure for converting units involves two steps.

1. Write a conversion factor.
2. Multiply the given set of units by the conversion factor to get the desired set of units.

Several examples of unit conversion will help illustrate this procedure.

Example #1
How many millimeters are there in one meter?

Example #2
How many nanoseconds are there in one kilosecond? (Hint: It is often necessary to carry out a conversion in two or more steps.)

Example #3
An automobile has a speed of 108 km/h. What is its speed in m/s?

Example #4
A bicycle is traveling at a speed of 10 m/s. What is its speed in km/h?

Measurement Worksheet

1. Express the following measurements in scientific notation.
   a) 5800 m
   b) 450 000 m
   c) 302 000 000 m
   d) 86 000 000 000 m

2. Express the following measurements in scientific notation.
   a) 0.000 508 kg
   b) 0.000 000 45 kg
   c) 0.003 600 kg
   d) 0.004 kg

3. Express the following measurements in scientific notation.
   a) 300 000 000 s
   b) 186 000 s
   c) 93 000 000 s

4. Express the following measurements in standard notation.
   a) 3.25×10^{8} kg
   b) 1.602×10^{-19} C
   c) 5.0 nanoseconds

5. Convert each of the following length measurements to its equivalent in meters.
   a) 1.1 cm
   b) 76.2 pm
   c) 2.1 km
   d) 0.123 Mm

6. Convert each of these mass measurements to its equivalent in kilograms.
   a) 147 g
   b) 11 μg
   c) 7.23 Mg
   d) 478 mg

7. Express 2500 m in kilometers and in centimeters.

8. One liter (L) is a volume of 10^{3} cm^{3}. How many cubic centimeters are in 2.5 milliliters?

9. How many picoseconds are there in 9.2 microseconds?

10. Rank the following mass measurements from smallest to largest: 11.6 mg, 1021 μg, 0.000 006 kg, 0.31 mg.

11. How many minutes make a microcentury?

12. When gasoline sells for $1.069 per gallon, what is the price in dollars per liter? (1 gallon = 3.7853 L)

13. A clock loses 3.0 s per day. By how many minutes will it be off at the end of one year (365 days)?

14. How many revolutions does the second hand of a clock make in three years? Assume no leap years in the interval.

15. The speed of sound at room temperature is 340 m/s. Express the speed of sound in units of kilometers per hour.