CHAPTER 1

Units and Conversions

Accurate measurements are at the heart of good data and good problem solving. Engineers need to be able to describe many different types of phenomena, such as distance, sound, light, force, and more.

At this point, you are working with a lot of units: grams for weight, joules for energy, newtons for force, meters for distance, seconds for time, and so on. For each type of measurement, there are several different units. For example, distance can be measured in feet, miles, and light-years.

Some Equalencies

Distance	
1 mile	1.6093 kilometers
1 foot	0.3048 meters
1 inch	2.54 centimeters
1 light-year	9.461×10^{12} kilometers
Volume	
1 milliliter	1 cubic centimeter
1 quart	0.9461 liters
1 gallon	3.7854 liters
1 fluid ounce	29.6 milliliters
Mass	
1 pound	0.4535924 kilograms
1 ounce	0.4535924 grams
1 metric ton	1000 kilograms
Force	
1 newton	1 kilogram meter per sec^2
Pressure	
1 pascal	1 newton per square meter
1 bar	0.98692 atmosphere
1 pound per square inch	6897 pascals
Energy	
1 joule	1 newton meter
1 calorie	4.184 joules
1 kilowatt-hour	3.6×10^6 joules

(You don't need to memorize these! Just remember that this page is here.)

In the metric system, prefixes are often used to express a multiple. Here are the common prefixes:

Common Prefixes for Metric Units

giga	$\times 10^9$
mega	$\times 10^6$
kilo	$\times 10^3$
milli	$\div 10^3$
micro	$\div 10^6$
nano	$\div 10^9$

(These are worth memorizing. Here's a mnemonic for the most common ones: "King Henry Doesn't Usually Drink Chocolate Milk" Or Kilo ($\times 10^3$), Hecto ($\times 10^2$), Deca ($\times 10^1$), Unit (for example: gram) ($\times 10^0$), Deci ($\times 10^{-1}$), Centi (1×0^{-2}), Mili ($\times 10^{-3}$).)

1.1 Conversion Factors

Here is a really handy trick to remembering how to do conversions between units.

Often, you will be given a table like the one above, and someone will ask you "How many miles are in 0.23 light-years?" You know that 1 mile = 1.6093 kilometers and that 1 light-year is 9.461×10^{12} kilometers. How do you do the conversion?

The trick is to treat the two parts of the equality as a fraction that equals 1. In other words, you think:

$$\frac{1 \text{ miles}}{1.6093 \text{ km}} = \frac{1.6093 \text{ km}}{1 \text{ miles}} = 1$$

and

$$\frac{1 \text{ light-years}}{9.461 \times 10^{12} \text{ km}} = \frac{9.461 \times 10^{12} \text{ km}}{1 \text{ light-years}} = 1$$

We call these fractions *conversion factors*.

Now, your problem is

$$0.23 \text{ light-years} \times \textit{ Some conversion factors} = ? \text{ miles}$$

Note that when you multiply fractions together, things in the numerators can cancel with things in the denominator:

$$\left(\frac{31\pi}{47}\right)\left(\frac{11}{37\pi}\right) = \left(\frac{31\cancel{\pi}}{47}\right)\left(\frac{11}{37\cancel{\pi}}\right) = \left(\frac{31}{47}\right)\left(\frac{11}{37}\right)$$

When working with conversion factors, you will do the same with the units:

$$0.23 \text{ light-years}\left(\frac{9.461 \times 10^{12} \text{ km}}{1 \text{ light-years}}\right)\left(\frac{1 \text{ miles}}{1.6093 \text{ km}}\right) =$$
$$0.23 \cancel{\text{light-years}}\left(\times\frac{9.461 \times 10^{12} \cancel{\text{km}}}{1 \cancel{\text{light-years}}}\right)\left(\frac{1 \text{ miles}}{1.6093 \cancel{\text{km}}}\right) = \frac{(0.23)(9.461 \times 10^{12})}{1.6093} \text{ miles}$$

Exercise 1 Simple Conversion Factors

Working Space

How many calories are in 4.5 kilowatt-hours?

Answer on Page 5

1.2 Conversion Factors and Ratios

Conversion factors also work on ratios. For example, if you are told that a bug is moving 0.5 feet every 120 milliseconds, what is that in meters per second?

The problem then is

$$\frac{0.5 \text{ feet}}{120 \text{ milliseconds}} = \frac{? \text{ m}}{\text{second}}$$

So you will need conversion factors to replace the "feet" with "meters" and to replace "milliseconds" with "seconds":

$$\left(\frac{0.5 \cancel{\text{ feet}}}{120 \cancel{\text{ milliseconds}}}\right)\left(\frac{0.3048 \text{ meters}}{1 \cancel{\text{ feet}}}\right)\left(\frac{1000 \cancel{\text{ milliseconds}}}{1 \text{ second}}\right) = \frac{(0.5)(0.3048)(1000)}{120} \text{ m/second}$$

Exercise 2 Conversion Factors

Working Space

The hole in the bottom of the boat lets in 0.1 gallons every 2 minutes. How many milliliters per second is that?

Answer on Page 5

1.3 When Conversion Factors Don't Work

Conversion factors only work when the units being converted are proportional to each other. Gallons and liters, for example, are proportional to each other: If you have n gallons, you have $n \times 3.7854$ liters.

Degrees celsius and degrees farenheit are *not* proportional to each other. If your food is n degrees celsius, it is $n \times \frac{9}{5} + 32$ degrees farenheit. You can't use conversion factors to convert celsius to farenheit.

Appendix A

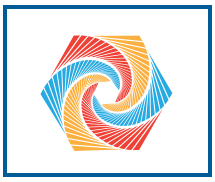
Answers to Exercises

Answer to Exercise 1 (on page 3)

$$4.5\ \cancel{\text{kWh}}\left(\frac{3.6\times 10^6\ \cancel{\text{joules}}}{1\ \cancel{\text{kWh}}}\right)\left(\frac{1\ \text{calories}}{4.184\ \cancel{\text{joules}}}\right)=\frac{(4.5)(3.6\times 10^6)}{4.184}=1.08\times 10^6\text{calories}$$

Answer to Exercise 2 (on page 4)

$$\frac{0.1\ \cancel{\text{gallons}}}{2\ \cancel{\text{minutes}}}\left(\frac{3.7854\ \cancel{\text{liters}}}{1\ \cancel{\text{gallons}}}\right)\left(\frac{1000\ \text{milliliters}}{1\ \cancel{\text{liters}}}\right)\left(\frac{1\ \cancel{\text{minutes}}}{60\ \text{seconds}}\right)=$$
$$\frac{(0.1)(3.7854)(1000)}{(2)(60)}\ \text{ml/second}=3.1545\ \text{ml/second}$$



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