

# Metric System

## Math Review -Dimensional Analysis

In 1960 the International Bureau of Weights and Measures (Sevres, France) adopted the "International System of Units", also known as "SI" units.

7 base units are used. All other SI units are derived from combinations of these base units:

length: meter (m)

mass: kilogram (kg)

time: second (s)

electric current: ampere (A)

temperature: Kelvin (K)

amount of substance: mole (mol)

luminous intensity: candela (cd)

General Punctuation Rules:

a) use space instead of comma to separate numbers into groups of three

ex: 63 000 000 m                      0.000 000 003 m

b) use decimals instead of fractions to express partial units

c) space between the numeric value and unit symbol

d) do not use periods after symbols

e) all abbreviations are singular

f) follow capitalization rules as given in problems

**The following pages reproduce a portion of the software program available to students. They demonstrate how to use metric prefixes, complete dimensional analysis problems, and reviews SI metrics. Please read each screen carefully. You might want to make notes. Additional problems are available from Mr. Jones.**

Metric Prefixes are combined with a unit to indicate that the unit has been multiplied by a certain power of 10. Prefixes are to be used to keep numerical values in tables, results, and specifications between 0.1 and 1000.

example: 144 000 N = 144 kN

Six basic prefixes are used commonly. They will be used to demonstrate the basic principles. Less common prefixes are given in the metric appendix.

The first example: kilo (abbreviated with lowercase 'k')

This prefix represents 3 decimal places, usually associated with 1000.

examples: 1 km = 1000 meters (1000 m)      2.3 kJ = 2 300 Joules (2 300 J)

Another example: centi (abbreviated with lowercase 'c')

This prefix represents 2 decimal places, usually associated with 0.01

examples: 100 cm = 1 meter (1 m)      2.3 E 2 cm = 2.3 meters (2.3 m)

Another commonly used metric prefix is milli ('m')

examples: 1000 mL = 1 liter (1 L)     $2.3 \times 10^3$  mL = 2.3 liters (2.3 L)

Less common but used occasionally are the following:

mega (M) 1 000 000 (1 E 6)

micro ( $\mu$ ) 0.000 001 (1 E - 6)

nano (n) 0.000 000 001 (1 E - 9)

The remaining prefixes and their multiplication factors can be seen in the metric appendix.

### Dimensional Analysis Examples

Dimensional analysis is also called the factor-label method of problem solving. It is a way of setting up a problem in a constant fashion that breaks the problem down into simple steps. Each step is a ratio that must equal 1, thus canceling out some preceding unit.

example problem: 4.4 km = ? m

solution:  $4.4 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} = 4400 \text{ m}$

(note that the 'km' cancel and you multiply 4.4 times 1000 to get your answer)

problem: 4.4 km = ? cm

solution:  $4.4 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{100 \text{ cm}}{1 \text{ m}} = 4.4 \times 10^5 \text{ cm}$

solution using scientific notation:  $4.4 \text{ km} \times \frac{1 \times 10^3 \text{ m}}{1 \text{ km}} \times \frac{1 \times 10^2 \text{ cm}}{1 \text{ m}} = 4.4 \times 10^5 \text{ cm}$

problem without metric prefixes: 4.4 weeks = ? seconds

solution:  $4.4 \text{ wk} \times \frac{7 \text{ day}}{1 \text{ wk}} \times \frac{24 \text{ hour}}{1 \text{ day}} \times \frac{60 \text{ minute}}{1 \text{ hour}} \times \frac{60 \text{ seconds}}{1 \text{ minute}} = 2.7 \times 10^7 \text{ s}$

some points of interest:

- $1 \times 10^3 \text{ m} = 1 \text{ km}$
- place the 1 with the large unit (then all other numbers in conversion are greater than 1)
- use base units whenever possible
- must know number of decimal places in each prefix

**Metric Problems:** the following problems solutions are part of the homework. Try them before you look at the solutions (no peeking).

- 4 g to cg
- 12 L to mL
- 12.5 mL to  $\mu\text{L}$
- 0.068 kL to L
- $8.5 \times 10^{-5}$  mg to cg
- $1.85 \times 10^{-6}$  Mm to nm

Solutions:

- $4 \text{ g} \times \frac{1 \text{ E } 2 \text{ cg}}{1 \text{ g}} = 4 \text{ E } 2 \text{ cg}$
- $12 \text{ L} \times \frac{1 \text{ E } 3 \text{ mL}}{1 \text{ L}} = 1.2 \text{ E } 4 \text{ mL}$
- $12.5 \text{ mL} \times \frac{1 \text{ L}}{1 \text{ E } 3 \text{ mL}} \times \frac{1 \text{ E } 9 \text{ }\mu\text{L}}{1 \text{ L}} = 1.25 \text{ E } 7 \text{ }\mu\text{L}$
- $0.068 \text{ kL} \times \frac{1 \text{ E } 3 \text{ L}}{1 \text{ L}} = 68 \text{ L}$
- $8.5 \text{ E } - 5 \text{ mg} \times \frac{1 \text{ g}}{1 \text{ E } 3 \text{ mg}} \times \frac{1 \text{ E } 2 \text{ cg}}{1 \text{ g}} = 8.5 \text{ E } - 6 \text{ cg}$
- $1.86 \text{ E } - 6 \text{ Mm} \times \frac{1 \text{ m}}{1 \text{ E } 6 \text{ Mm}} \times \frac{1 \text{ E } 9 \text{ nm}}{1 \text{ m}} = 1.86 \text{ E } - 3 \text{ nm}$

### Metric Appendix

Name	Symbol	Multiplication Factor
exa	E	1 E 18
petra	P	1 E 15
tera	T	1 E 12
giga	G	1E 9
mega	M	1 E 6
kilo	k	1E 3
hecto	h	1 E 2
deka	da	1 E 1
deci	d	1 E - 1
centi	c	1 E - 2
milli	m	1 E - 3
micro	$\mu$	1 E - 6
nano	n	1 E - 9
pico	p	1 E - 12
femto	f	1 E - 15
atto	a	1 E - 18

## SI Base Units

Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Temperature	Kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

## Common Conversions

$$1 \text{ mile} = 5280 \text{ ft}$$

$$1 \text{ km} = 1000 \text{ m}$$

$$1 \text{ km} = 0.6214 \text{ mile}$$

$$1 \text{ mile} = 1760 \text{ yd}$$

$$1 \text{ hour} = 3600 \text{ s}$$

$$1 \text{ m} = 3.28 \text{ ft}$$

$$1 \text{ m} = 100 \text{ cm}$$

$$1000 \text{ m} = 0.6214 \text{ mile}$$

$$1 \text{ lb} = 454 \text{ g}$$

$$1 \text{ in} = 2.54 \text{ cm}$$

$$1 \text{ L} = 1.06 \text{ qt}$$

$$1 \text{ year} = 365.24 \text{ day}$$

$$1 \text{ slug} = 14.6 \text{ kg}$$

$$1 \text{ mL} = 1 \text{ cm}^3 \text{ for all substances}$$

$$1 \text{ mL} = 1 \text{ cm}^3 = 1 \text{ g} \text{ for pure water only}$$

## Significant Figures

\* There is a difference between pure numbers (as used in math classes) and measured quantities (such as 35.6 mL of acid).

\* Measurement tools often limit our ability to measure quantities.

\* We must be aware of the accuracy limits of each piece of lab equipment that we use and record our data to the proper number of significant figures.

\* You are always allowed one estimated figure in measurements.

\* When measured quantities are given to you, it is assumed that the proper number of significant figures were recorded. (all measurements in scientific notation must be recorded to the proper number of significant figures).

\* When using conversions, '1' is considered to be correct to several significant figures.

## Rules for Counting Significant Figures

Rule: All non-zero digits are significant.

12.83 cm [4]    16935 g [5]

Rule: Zeros between other significant figures are significant.

12 038 cm [5]    169.04 g [5]    70 304 g [ ]    395.01 kg [ ]

Rule: Zeros to the right of a decimal point and to the right of a number are significant.

12.380 cm [5]    169.00 m [5]    3.010 mL [4]    1.30 kg [ ]    1691.100 cm [ ]

Rule: A zero standing alone to the left of a decimal point is not significant.

0.421 g [3]    0.5 m [ ]

Rule: Zeros to the right of the decimal and to the left of a number are not significant.

0.000 421 mg [3]    0.001 80 cm [3]    0.010 kg [ ]    0.01010 m [ ]

Rule: Zeros to the right of the last number but left of the decimal point may or may not be significant. This information is known only to the person that made the measurement. Use scientific notation when in doubt. The use of a bar over the last significant zero is acceptable as well as using the decimal point to indicate that all digits to its left are significant.

4000. g [4]    3400 kg [2]    69 700. mL [ ]    4.50 E 2 g [ ]

## Rounding Rules

When rounding examine the digit to the right of the digit that is to be last (this number is called the trigger):

a) if the trigger is less than 5, drop it and all the digits to the right of it

b) if the trigger is more than 5, increase by 1 the number to be rounded

C) if the trigger is 5, round the number so that it will be even

63.5347 m [4] = 62.53 m

3.787 21 m [3] = 3.79 m

726.835 m [5] = 726.84 m

24.8514 m [3] = 24.8 m

## Multiplication and Division using Significant Figures

Rule: In multiplication and division, the result may have *no more* significant figures than the factor with the fewest number of significant figures.

example:  $2.52 \text{ m} \times 1.0004243 \text{ m} = 2.521069236 \text{ m}^2$  but must be recorded as  $2.52 \text{ m}^2$  (3 sig figs)

example:  $7540 \text{ m} \times 1.3 \text{ m} = 9802.000 \text{ m}^2$  but must be recorded as  $9800 \text{ m}^2$  (only 2 sig figs)

Rule: When adding and subtracting numbers that come from measurements, arrange the numbers in columnar form. The final answer can contain only as many decimal places as found in the measurement with the fewest number of decimal places.

example:  $134.050 \text{ m} + 1.23 \text{ m} =$

$$\begin{array}{r} 134.050 \text{ m} \\ + 1.23 \text{ m} \\ \hline 135.28 \text{ m} \end{array}$$
 (2 decimal places)

Directions: Perform all the operations using your calculator and record the answer with the proper number of significant figures. See Mr. Jones for answers.

- $$\frac{(3.4617 \text{ E } 2)(5.61 \text{ E } -4)}{(9.87 \text{ E } 5)(3.1)(1.171 \text{ E } 4)}$$
- $$\frac{(3.52164 \text{ E } 2)(3.1741 \text{ E } 5)}{(8.22 \text{ E } 7)(4.65217 \text{ E } -3)(9.711 \text{ E } 4)}$$
- $$\frac{(1.8741 \text{ E } 11)}{(5.6 \text{ E } 4)(2.173 \text{ E } 8)}$$
- $$\frac{(1.745 \text{ E } -2)(9.51 \text{ E } -7)}{(16.21)(9.346 \text{ E } -10)}$$
- $$\frac{(3.4721 \text{ E } 5)}{(5.6145 \text{ E } 7)(9.5 \text{ E } 1)}$$

## Word Problems using Significant Figures

Directions: Solve the following word problems and record the answer using the proper number of sig figs. Use 3.1416 for  $\pi$ . See Mr. Jones for answers.

- The volume of a cylinder is:  $V = \pi r^2 L$   
What is the volume of a cylinder that has a radius of 0.0631 m and a length of 2.0 m?
- The 100 sheets of a textbook measure 0.02375 m. What is the thickness of only 1 of those sheets?
- formula:  $t = d/V$   
How long does it take light traveling at  $2.99793 \text{ E } 8 \text{ m/s}$  to travel across a room that is 6.2 m long?

4. formula:  $a_c = 4\pi r/T^2$   
Find the centripetal acceleration ( $a_c$ ) when the radius is 1.261 m and the period (T) is 0.64 s.
5. formula:  $d = 1/2 a t^2$   
What is the distance traveled by a body from rest when the gravitational acceleration (a) is  $9.80665 \text{ m/s}^2$  and the fall time (t) is 13.29 s?
6. I massed 150 tacks. The total mass was 10.35 g. What is the mass of a single tack?


## Word Problems Using Significant Figures

Rule: When calculating the number of significant figures allowed in an answer, the following categories are NOT considered:

 numbers representing a numerical count

example: 25 students, each carrying 2.693 54 kg of sugar

$$\rightarrow 25 \times 2.693 \text{ 54 kg} = 67.338 \text{ 5 kg}$$

 numbers that are part of a mathematical formula

example: volume of a sphere =  $\frac{4}{3} \pi r^3$  for sphere with radius 2.11111 cm

$$\rightarrow \frac{4}{3} \pi 2.11111^3 = 39.4114 \text{ cm}^3 \quad (\text{using } 3.141 \text{ 6 for } \pi)$$

 conversions

1 km = 1000 m the 1 is considered to have several significant figures

Sample problems: (not found in other practice problem sheets)

1. What is the perimeter of a rectangle with a length of 2.1 m and a width of 0.65 m?

$$P = 2l + 2w$$

2. The period of an oscillating spring is  $T = 2\sqrt{\pi(m/k)}$ . If the spring constant (k) is 0.9531 N/m and the mass (m) is 1.2 kg, what is the period?

3. How long does it take light traveling at  $2.99793 \times 10^8$  m/s to travel across a room that is 6.2 m long?
4. The 100 sheets of a textbook measure 0.02375 m. What is the thickness of only 1 of those sheets?
5. The period of revolution for Uranus is 30 685.93 days. How many hours is that?
6. If the thickness of 1 sheet of paper is 0.023 7 cm, what is the thickness of 6 of those sheets?
7. The perimeter of a polygon is the sum of its sides. What is the perimeter of a polygon with sides of 25.623 m, 5.97 m, 3.21 m, 0.2 m, and 4.621 m?
8. The circumference of an ellipse =  $2\sqrt{\pi((a^2 + b^2)/2)}$  ( $\pi = 3.1416$ ) What is the circumference of an ellipse that has a semi-major axis (a) of 6.987654 m and a semi-minor axis (b) of 2 m?

Answers available from Mr. Jones

## Scientific Notation

Integral Powers of 10

$$10^0 = 1 \text{ E } 0 = 1 \quad (1 \times 10^0 \text{ is acceptable})$$

$$10^1 = 1 \text{ E } 1 = 10$$

$$10^2 = 1 \text{ E } 2 = 100$$

$$10^6 = 1 \text{ E } 6 = 1\,000\,000$$

$$10^{-1} = 1 \text{ E } -1 = 0.1$$

$$10^{-2} = 1 \text{ E } -2 = 0.01$$

$$10^{-6} = 1 \text{ E } -6 = 0.000\ 001$$

Proper Notation:

Place the leftmost significant figure to the left of the decimal and display the rest of the figures (significant only) to the right of the decimal following rounding rules. There can only be 1 integer to the left of the decimal.

example: 93 000 000 m = 9.3 E 7 m

$$0.000\ 028 \text{ in} = 2.8 \text{ E } -5 \text{ in}$$

Decimal points and a bar over the last significant zero will be demonstrated in class.

Multiplying measured quantities using scientific notation:

Rule: multiply the numbers and add exponents:

example:  $(9.0 \text{ E } 3 \text{ m})(7.0 \text{ E } 2 \text{ m}) = 63 \text{ E } 5 \text{ m}^2 = 6.3 \text{ E } 6 \text{ m}^2$

Dividing in scientific notation:

Rule: Divide the numbers and subtract the exponents:

example:  $(4.5 \text{ E } -6 \text{ m}^2) / (1.5 \text{ E } -2 \text{ m}) = 3.0 \text{ E } -4 \text{ m}$

## Dimensional Analysis

Dimensional analysis is also known as the factor-label method of problem solving. It involves the use of conversions to systematically change units.

The following examples may help:

$$1.0 \text{ ft} = \underline{\hspace{2cm}} \text{ cm}$$

$$1.0 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 30.48 \text{ cm} = 30. \text{ cm}$$

$$63 \text{ s} = \underline{\hspace{2cm}} \text{ ns (nanoseconds)}$$

$$63 \text{ s} \times \frac{1 \text{ E } 9 \text{ ns}}{1 \text{ s}} = 63 \text{ E } 9 \text{ ns} = 6.3 \text{ E } 10 \text{ ns}$$

$$1.00 \text{ year} = \underline{\hspace{2cm}} \text{ s}$$

$$1.00 \text{ yr} \times \frac{365.24 \text{ day}}{1 \text{ yr}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{3600 \text{ s}}{1 \text{ hr}} = 3.2 \text{ E } 7 \text{ s}$$