

## THE PROBLEM

Many numbers come to us in “convenient” forms—you may have \$8 in your pocket; perhaps you’re 5 ft 10 in tall; or maybe you jog 4 mi every day. In your math classes, you often dealt with numbers between 1 and 10, with the occasional 0—for example  $x^2 + 2x - 4 = 0$ . The problem is that there is no system of units in which we could measure all the things in the universe and come up with such convenient numbers. In SI units, for instance, the standard unit of length is the meter. The distance to “nearby” Alpha Centauri is 43 000 000 000 000 000 m, while the radius of a proton is about 0.000 000 000 000 001 2 m.

As scientists began measuring larger and larger and smaller and smaller quantities, they noticed that they went through a lot of pencils and paper writing all those zeros; they began living on a diet of Cheerios and Spaghettios. This was not a good thing.

## THE SOLUTION

Scientific notation to the rescue! Scientific notation is a method of writing numbers in terms of powers of ten. For instance, 100 is  $10^2$ , 1000 is  $10^3$ , etc. The number 700 is written  $7 \times 10^2$ , 7000 is written  $7 \times 10^3$ .


All numbers written in scientific notation have the form:  $A \times 10^n$

where  $A$  is a number greater than or equal to 1 and less than 10 (i.e.,  $1 \leq A < 10$ ) and  $n$  is the power of 10 ( $n$  can be positive or negative). Here’s a “cookbook” method of determining a number’s scientific notation:

- 1. Determine  $A$**  by shifting the decimal point to the left or right until only one non-zero number is to the left of it.  $A$  should contain only the significant figures of the original number.
- 2. Determine  $n$**  by counting the number of places the decimal has been shifted; if it was moved to the left,  $n$  is positive. If it has been moved to the right,  $n$  is negative.

### Example 1

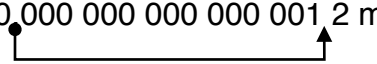
Earth’s mass:

5 980 000 000 000 000 000 000 000.0 kg  


Earth’s mass =  $5.98 \times 10^{24}$  kg

### Example 2

Radius of a proton:

0.000 000 000 000 001 2 m  


Radius of a proton =  $1.2 \times 10^{-15}$  m

## CALCULATOR AND COMPUTER DISPLAY OF SCIENTIFIC NOTATION

Many calculators display a scientific notation in an unfamiliar way. For example, the Earth’s mass would be displayed as  $5.98 \ 24$  and the proton’s radius would be displayed as  $1.2 \ -15$ . Notice most calculators don’t keep track of units. That’s what you’re around for. They’re also too lazy to spell out the “ $\times 10$ ” business. You get used to it.

Computers have their own way of displaying scientific notation. A computer might spit out the mass of the Earth as  $5.98\text{E}+24$  and the radius of the proton as  $1.2\text{E}-15$ . Notice the use of the “E” to denote “ $\times 10$ .” Again, nothing here to be frightened of.

# PhyzReference: Engineering & Prefix Notation

## ENGINEERING NOTATION

In engineering notation, you are confined to using every third power of ten *only*. For example, 12,500 becomes  $12.5 \times 10^3$  and not  $1.25 \times 10^4$ . Numbers written in engineering notation follow the form:

$$B \times 10^m$$

where  $B$  is a number greater than or equal to 1 and less than 1000 (i.e.,  $1 \leq B < 1000$ ) and  $m$  is the power of 10 ( $m$  can be positive or negative). The exponent  $m$  must be a multiple of three (e.g.  $-9, 6, 12, -6$ , etc).

## THE SI PREFIX NOTATION

In the metric (SI) system, the power of 10 notation can be replaced by prefixes that denote a certain power of 10. For example, *kilo* denotes  $10^3$  while *micro* denotes  $10^{-6}$ . Each prefix also has an abbreviation. The abbreviation for kilo is k and the abbreviation for micro is  $\mu$ . So 1000 g (one thousand grams) is  $10^3$  g or 1 kg (one kilogram), while 0.000001 m (one one millionth of a meter) is  $10^{-6}$  m or 1  $\mu\text{m}$  (one micrometer). There is a prefix for every third power of 10.

<i>Prefix</i>	<i>Pronunciation</i>	<i>Abbrev.</i>	<i>Value</i>	<i>Prefix</i>	<i>Pronunciation</i>	<i>Abbrev.</i>	<i>Value</i>
yotta	YAH tuh	Y	$10^{24}$	milli	MIH lee	m	$10^{-3}$
zetta	ZEH tuh	Z	$10^{21}$	micro	MY kroe	$\mu$	$10^{-6}$
exa	EK suh	E	$10^{18}$	nano	NAH noe	n	$10^{-9}$
peta	PEE tuh	P	$10^{15}$	pico	PEE koe	p	$10^{-12}$
tera	TARE uh	T	$10^{12}$	femto	FEM toe	f	$10^{-15}$
giga	JEE guh	G	$10^9$	atto	AT toe	a	$10^{-18}$
mega	MEH guh	M	$10^6$	zepto	ZEP toe	z	$10^{-21}$
kilo	KIH loe	k	$10^3$	yocto	YOK toe	y	$10^{-24}$

Avoid prefixes that do not represent a third power of ten, such as hecto (h) =  $10^2$ , deka (da) =  $10^1$ , deci (d) =  $10^{-1}$ , and centi (c) =  $10^{-2}$ . It is better to refer to 0.050 g as 50 mg than 5 cg.

NOTE: A  $\mu\text{m}$  (a micrometer) is sometimes called a *micron*, designated simply  $\mu$ . Human hair is approximately 100  $\mu$  in diameter. Also, *Ångstroms* (Å) refer to a distance of  $10^{-10}$  meters. Atoms are approximately 1 Å in diameter.

If a number has been expressed in engineering notation, it can be abbreviated in SI prefix notation easily and directly. Consider the following examples.

<i>"Raw" Number</i>	<i>Sci. Notation</i>	<i>Eng. Notation</i>	<i>SI Prefix Notation</i>	<i>In words</i>
35 400 000 W	$3.54 \times 10^7$ W	$35.4 \times 10^6$ W	35.4 MW	35.4 megawatts
0.120 s	$1.2 \times 10^{-1}$ s	$120 \times 10^{-3}$ s	120 ms	120 milliseconds

## CAUTION • DANGER • WARNING • CAUTION • DANGER • WARNING • CAUTION

**Never** enter numbers in their abbreviated form into any calculations; **always** expand numbers into scientific or engineering notation first. If the numbers above had to be multiplied, it would be *wrong* to multiply  $35.4 \text{ MW} \cdot 120 \text{ ms}$ !!! It would be *correct* to multiply  $35\,400\,000 \text{ W} \cdot 0.120 \text{ s}$  or  $3.54 \times 10^7 \text{ W} \cdot 1.2 \times 10^{-1} \text{ s}$  or  $35.4 \times 10^6 \text{ W} \cdot 120 \times 10^{-3} \text{ s}$ .