Scientific Quantities and SI Units
Mass – kg
Distance – m
Time – s
Area – m^2
Volume – m^3
Temperature – K
Mole – $6.023*10^{23}$ Avogadro's number of things
Density (ρ) – kg/m^3 (Mass per volume)
Velocity – m/s (Distance per unit time)
Acceleration – m/s^2 (Velocity per time, change in velocity/change in time)
Force – Newton, N, $kg*m/s^2$ (Mass times acceleration)
Energy – Joules, $J = Nm = kg*m/s^2 * m$ (Force times distance)
Pressure – $N/m^2 =$ Pascale, Pa (Force divided by area) $kg*m/s^2 *1/m^2$
Power – Watt = J/s (energy per time)

Scientific Notation

Scientific notation is the way that scientists easily handle very large numbers or very small numbers. So, how does this work? W e can think of 5.6×10^{-9} as the product of two numbers: 5.6 (the digit term) and 10^{-9} (the exponential term).

Here are some examples of scientific notation.

$10000 = 1 \times 10^4$	$24327 = 2.4327 \times 10^4$
$1000 = 1 \times 10^3$	$7354 = 7.354 \times 10^3$
$100 = 1 \times 10^2$	$482 = 4.82 \times 10^2$
$10 = 1 \times 10^1$	$89 = 8.9 \times 10^1$ (not usually done)
$1 = 10^0$	
$1/10 = 0.1 = 1 \times 10^{-1}$	$0.32 = 3.2 \times 10^{-1}$ (not usually done)
$1/100 = 0.01 = 1 \times 10^{-2}$	$0.053 = 5.3 \times 10^{-2}$
$1/1000 = 0.001 = 1 \times 10^{-3}$	$0.0078 = 7.8 \times 10^{-3}$
$1/10000 = 0.0001 = 1 \times 10^{-4}$	$0.00044 = 4.4 \times 10^{-4}$

As you can see, the exponent of 10 is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

In scientific notation, the digit term indicates the number of significant figures in the number. The exponential term only places the decimal point. As an example,
$$46600000 = 4.66 \times 10^7$$
This number only has 3 significant figures. The zeros are not significant; they are only holding a place. As another example,

$$0.00053 = 5.3 \times 10^{-4}$$

This number has 2 significant figures. The zeros are only place holders.

Significant Figures

- no more than 3 sig figs usually

Scientific notation is the most reliable way of expressing a number to a given number of significant figures. In scientific notation, the power of ten is insignificant. For instance, if one wishes to express the number 2000 to varying degrees of certainty:

$2000 \longrightarrow 2 \times 10^3$ is expressed to one significant figure

$2000 \longrightarrow 2.0 \times 10^3$ is expressed to two significant figures

When handling significant figures in calculations, two rules are applied:

Multiplication and division -- **round the final result to the least number of significant figures of any one term**, for example:

$$\frac{(15.03)(4.87)}{1.987} = 36.8$$

The answer, 36.8, is rounded to three significant figures, because least number of significant figures was found in the term, 4.87.

Addition and subtraction -- round the final result to the least number of decimal places, regardless of the significant figures of any one term, for example:

$$
\begin{array}{r}
1.003 \\
13.45 \\
+ \ 0.0057 \\
\hline
14.4587 \quad \text{rounds off to} \quad 14.46
\end{array}
$$

The answer, 14.4587, was rounded to two decimal places, since the least number of decimal places found in the given terms was 2 (in the term, 13.45).

Suppose more than one mathematical operation is involved in the calculation? Such a calculation may be "deceptive" as to how many significant figures are actually involved. For instance:

$$\frac{(8.34 - 7.84)}{(15.05)(2.01)} = ?$$

The subtraction in the numerator must be performed first to establish the number of significant figures in the numerator. The subtraction results in:

$$\frac{0.50}{(15.05)(2.01)} = 0.017$$

Since the subtraction in the numerator resulted in a number to two significant figures the final result must be rounded to two significant figures.

Example 1: How much pressure does a standing person exert on the floor

a) Find area:

$$7in*10in = 70in^2 * \frac{2.54cm}{1in} * \frac{2.54cm}{1in} * \frac{1m}{100cm} * \frac{1m}{100cm} = 0.045m^2$$

b) Find Force: N = kg * m/s2
F = mass*acceleration (in this case acceleration is gravity)
Weight = mass * 9.8 m/s2

$$mass = 155lb * \frac{1kg}{2.2lbs} \cong 70kg \quad \text{(go over conversion of lb to kg)}$$

$$F = (70kg) * \left(9.8\frac{m}{s}\right) \cong 700N$$

$$P = \frac{700N}{0.045m^2} = 1.5*10^4 Pa$$

E. Ideal Gas Laws

$$PV = nRT \quad \text{where} \quad P = \text{Pressure} \quad R = \text{Universal gas constant, } 8.314\frac{J}{mol * K} \text{ in SI units}$$

$V = $ Volume
$n = $ Number of moles $T = $ Temperature in Kelvin

$$PV = \frac{mRT}{M} \quad \text{where} \quad m = \text{mass of gas}$$

M = Molecular weight of gas (from periodic table)
Of air = 29 g/mole in a mole of normal air
$O_2 = 32g/mol$, $N_2 = 14g/mol$, $H_2O = 18g/mol$

$$P = \frac{\rho RT}{M} \quad \text{where} \quad \rho = \text{density of gas (density is in units of kg/m}^3 \text{ Mass per Volume!)}$$

$P = cRT$ where $c = $ concentration of gas (units are moles/m³)

Unit conversion within the problem!

$$Pa = \frac{N}{m^2} = \frac{\frac{kg*m}{s^2}}{m^2} \qquad J = Nm = \frac{kg*m}{s^2}*m \qquad N = \frac{kg*m}{s^2}$$

Example 2: What is the density of air at Room Temperature?

$$P = \frac{\rho RT}{M} \rightarrow \frac{PM}{RT} = \rho \quad \text{using the values:} \quad R = 8.314 \frac{J}{mol * R}$$

M = 29 kg/mol
T = 20°C = 20 + 273 K = 293K
P = 1atm = 100kPa = 100000Pa = 1.0*10⁵Pa

Plug in the values:

$$\rho = \frac{(1.0*10^5 Pa)*.029\frac{kg}{mol}}{8.314\frac{J}{mol*K}*293K} = 1.2\frac{kg}{m^3}$$

Alternatively, can approximate ideal gas law for use in atmosphere by using the gas constant for dry air R_d:
R_d = R/M_{air} = 8314.3/28.97 = 287 J deg⁻¹ kg⁻¹

Then can use $P = \rho R_d T$, which is easier to calculate. This formula does not take into account the slight impact of water vapor molecules in the air on its molecular weight.

$$\rho = \frac{(1.0*10^5 Pa)*}{287\frac{J}{K*kg}293K} = 1.2\frac{kg}{m^3}$$