By the way, even if you're just doing a quick calculation, I recommend **not** using a calculator. Enter the data into an Excel spreadsheet so that you can add/change/scrutinize/save calculations as needed. Sometimes I see an obviously invalid result and when I ask, "How did you get that result? What numbers did you use?" the answer is "I put the numbers into the calculator and this was the result I got." But how do you know you entered the numbers and formulas correctly? What if you need to re-do the calculation for a slightly different set of numbers?

Examples of the use of units and scrutiny

These examples, particularly the first one, also introduce the concept of "back of the envelope" estimates, a powerful engineering tool.

Example 1. Drag force and power requirements for an automobile

A car with good aerodynamics has a drag coefficient (C_D) of 0.2. The drag coefficient is defined as the ratio of the drag force (F_D) to the *dynamic pressure* of the flow = $\frac{1}{2}\rho v^2$ (where ρ is the fluid density and v the fluid velocity far from the object) multiplied by the cross-section area (A) of the object, *i.e.*

$$F_D = \frac{1}{2} C_D \rho v^2 A \qquad \text{(Equation 7)}$$

The density of air at standard conditions is 1.18 kg/m^3.

(a) Estimate the power required to overcome the aerodynamic drag of such a car at 60 miles per hour.

Power = Force x velocity

v = 60 miles/hour x (5280 ft/mile) x (m/3.28 ft) x (hour/60 min) x (min/60 s) = 26.8 m/s

Estimate cross-section area of car as 2 m x 3 m = 6 m^2

F_D = 0.5 x 0.2 x 1.18 kg/m^3 x (26.8 m/s)^2 x 6 m^2 = 510 kg m/s^2 = 510 Newton

Power = F_D x v = 510 kg m/s^2 x 26.8 m/s = 1.37 x 10^4 kg m^2/s^3 = 1.37 x 10^4 W = 18.3 horsepower, which is reasonable

(b) Estimate the gas mileage of such a car. The heating value of gasoline is 4.3 x 10^7 J/kg and its density is 750 kg/m^3.

Fuel mass flow required = power (Joules/s) / heating value (Joules/kg)
= 1.37 x 10^4 kg m^2/s^3 / 4.3 x 10^7 J/kg = 3.19 x 10^{-4} kg/s

Fuel volume flow required = mass flow / density
= 3.19 x 10^{-4} kg/s / 750 kg/m^3 = 4.25 x 10^{-7} m^3/s x (3.281 ft/m)^3 x 7.48 gal/ft^3
= 1.12 x 10^{-4} gal/sec