Tips for Doing Calculations

When doing a calculation on an aspect of your machine please use the following format.

1. What is the goal of your calculation? What are you trying to estimate?
2. What is your model for the physical situation?
3. What is your method of solution (is it graphical? or are you solving a set of simultaneous equations? Is the solution of a differential equation with boundary values, etc.?)
4. Execute the solution.
5. Discuss the results and summarize your conclusions.

When doing a calculation, especially a complicated one, it's easy to make a mistake and come out with an answer that can be quite wrong. It's important, therefore, to develop skills to avoid such pitfalls. Here are some tips:

1. When you derive a relationship, a very effective check is to make sure that the terms are all dimensionally correct. Reduce each quantity to its basic expression in mass, length and time and make sure that everything balances.
2. You often have to work with quantities such as material properties provided in odd systems of units. You must therefore, become facile with unit conversion and check your units to make sure that everything balances in the particular system of units that you are using. Once you have an expression that passes the unit test, you can look at it to see if the sense of things is right. Thus, if you're looking at a deflection of a beam you would expect it to predict a higher deflection for larger forces.
3. Another good check is to look at extreme and or limiting cases. Thus, it is often possible to reduce a complex expression to a simpler one by looking at limiting cases where some quantity goes to zero or to infinity. Often you have available to you solutions to these simpler problems. If your formula for a complex problem reduces to a published formula for the simpler problem in a limiting case, it can give you quite a bit of confidence in your solution.
4. Do a sanity check. Compare your results to your intuition/experience. If something doesn't seem right you may find that you've made a mistake. On the other hand you may find that you haven't and this can serve as a good new data point for refining your intuition. Another way to do a sanity check is to find an analogous situation in an existing piece of hardware and see if your answer is in the same ballpark. If your designing a toy and your analysis says you need a 1 kilowatt motor while comparable toys use 4 watt motors, you may have made a mistake somewhere. Experiments are always a great way to do sanity checks. You can often build a small element of your machine (and build it in a quick fashion) and get an order of magnitude estimate of an answer to see if your prediction is in the right ballpark. Another way to do a type of experiment is to do a graphical analysis. This is particularly useful for linkages and kinematic relationships. Thus, you can derive an analytic expression and check it for a few test cases simply by laying out the geometry. If you predict well for a few special cases, you probably predict well for all cases.

For an example of calculations required for a contest machine, see this analysis of the 1999 2.007 table physics.*

Please see the section on using software to help with engineering calculations.*