Tips on Problem Solving in Thermo-Fluids Engineering

1. Define the system:
    a. Ask yourself what physically is happening in the problem you are trying to solve. Take notes when you explain to yourself what the problem is about.
    b. Make a **sketch** of the situation and define boundaries of the system to be analyzed. Place the system boundaries where you know something. Note all known / given quantities.
    c. A control mass is a fixed piece of matter, a control volume is a defined region in space through which matter and energy is transferred. Clearly identify your choice.

2. Define the forces or flows:
    a. If you are doing a momentum analysis, indicate the significant forces on the sketch and define their sign convention by an arrow. Once you define the sign convention you must stick to it throughout your analysis.
    b. If you are doing an energy analysis show all the significant energy flows on the sketch (as heat, as work and energy transported by the flow) and define their sign convention by an arrow. Once you define the sign convention you must again stick to it throughout your analysis.

3. State your assumptions:
    a. List the simplifying assumptions (e.g. steady-state, 1-D flow, adiabatic device, perfect gas, adiabatic reversible process etc.).
    b. Your list of assumptions and your sketch define the **model** that you are using.

4. Apply fundamental principles:
    a. Express the pertinent basic principle [**conservation of mass, conservation of momentum, conservation of energy (1st law), 2nd law of thermodynamics, Gibbs, etc.]** as it applies to your defined system in terms of the symbols defined on your system sketch (e.g. if you define a control mass, use control mass form of 1st law etc.)
    b. Most of missteps occur at this point: start with basic principle in **fundamental form**, apply your assumptions (cross out terms if possible) and make sure there is a one-to-one correspondence between the terms on your sketch and the terms in your basic equation.

c. Conduct a sanity check and walk yourself through the equation you have written. Ask yourself why each of the terms should be there or should not be there, and whether this is consistent with your assumptions.

5. Bring in auxiliary information:

   a. You may need to use the equation of state, rate equations, or other information. It is a very good idea to **count the unknowns** and the **equations** and to check that these numbers are the same before you do the algebra.

   b. It is extremely helpful to use **thermodynamic coordinates** – try to draw the processes in an appropriate diagram (T-s, h-s, p-V etc.) and again label the states consistently with your sketch. This helps you visualize the processes and apply the fundamental principles.

   c. Ask yourself what the curves you sketched **imply** (e.g. if I move along this curve, an adiabatic process, in my T-s diagram the entropy must increase because there are internal irreversibilities). The diagrams help you identify states that are known / unknown and clearly depict the connection and relationships between the states and the state changes.

6. Solve the problem:

   a. Solve the equations algebraically if this is easy or desirable, or numerically if algebraic solutions are tedious or impractical.

   b. **Check your units**. This is the best sanity check on your algebra. If an answer has units, make sure you give them.

7. Non-dimensionalize your results:

   a. If your analysis is of general utility, you may want to express your results in **non-dimensional form** by defining appropriate dimensionless variables (e.g. $(p - p_0)/(\frac{1}{2}\rho v^2)$, x/d etc.).

8. Discuss your results:

   a. It may be useful, depending on the situation, to discuss the **significance** of your result.

   b. Address **limitations** of your solution and revisit your assumptions and modeling simplifications.

9. Make your analysis "read":

   a. Number your equations, refer to them by number, and **insert a few words** here and there so that the reader can follow your analysis without having to guess what you are doing.