PROBLEM-SOLVING in SCIENCE and ENGINEERING

Gary L. Bertrand, Professor of Chemistry
University of Missouri-Rolla

First Thoughts

You aren't expected to know how to work a problem as soon as you read it. Solving a problem is a form of combat, requiring stamina, endurance, and skill - all of which result from practice, practice, and more practice. Allow yourself sufficient time to apply these principles in doing assignments. Hurrying through a problem cheats you of most of its benefits. Waiting until the last minute to "do" assignments makes you hurry through the problems, and you develop the habit of sloppy work - so you lose twice. The goal of the student is not to get the problem "done". The goal is to learn and grow from "doing" the problem.

The Process

The process of solving problems is based on **Analysis** (taking apart) and **Synthesis** (putting together). You **analyze** the problem by taking it apart and identifying its components, then you put those components back together with additional components or in a different arrangement to **synthesize** the answer. Simple problems usually involve rearranging the components. In complex problems, you must identify the additional components or information that is needed, and you must be able to find it.

On Answers

If the answer is available, you should **not** look at it until you are reasonably sure that you have worked the problem correctly. There is no answer book on the exam or on the job - if the boss could look up the answer, why would he pay you to work the problem? Many students have developed the art of working backwards from the answer. This is a very useful process if you substitute a symbol (X) for the answer and work backwards, but it is counter-productive if you use a number and look for some combination of numbers that will produce that result.

When you have completed the problem, don't let your answer get lost in a lot of scratch-outs, scribbling, and scrawls. The grader (or your boss) will look for the answer first, then will check on how you arrived at it. You've invested time and effort in coming up with that answer, and right or wrong, it represents YOU. Put it out there, bold and confident, for all the world to see - they'll either find it anyway, or mark the problem wrong. If your answer is right, you should be proud of it. If it's wrong, there is nothing to be ashamed of if you've given it your best effort - finding out why it's wrong is part of the learning process. If you don't find out why it's wrong, or you haven't given your best effort to solve the problem, you have wasted the time and effort you have invested.

Estimates and Guesstimates

In many real-world problems, an order-of-magnitude **estimate** is sufficient and a precise answer may be impossible or unnecessary. Approximate values for dimensions and conditions may be used for the calculation. An **estimate** is based on approximations that are known to be reasonable through experience or available information. A **guesstimate** is made when such information is unavailable. All guesstimates and approximations should be stated, so that they may be upgraded if a better estimate becomes necessary.

Whenever you perform numerical calculations in a problem, it is a good idea to also do a rough or approximate calculation, preferably "in your head". This provides a check on the calculation, especially on decimal points and powers of ten where errors often occur, and also helps develop skills in estimation.

SOLVING PROBLEMS with READ IT

Read and **R**e-state
Evaluate and **E**xplore
Arrange and **A**ttack
Do it and **D**efend your answer
Identify the Principles **I**llustrated
Try a different **T**actic

Read and **Re-state**: Carefully **read** the problem so that you understand it well enough to **re-state** it in a different way, even if it's no more than "They're telling me this and this; and they want to know that."

Evaluate and **Explore**: **Evaluate** what is given to see if it contains "hidden" information. **Evaluate** the question in terms of information that might be helpful in coming up with an answer. The information given is a starting point, the answer is the destination - there should be a logical path between them. **Explore** your resources - text, notes, study materials - to find the path, which is usually an equation or a set of equations. If you run out of ideas on working from the starting point to the destination, try working back from the destination to the starting point.

Arrange and **Attack**: **Arrange** the given information in the symbols and units required by the equation or path. Identify and define any intermediate quantities you may need to calculate. If the path is complex, sketch out your plan of **attack**.

Do it and **Defend** your answer: **Do** the necessary calculations. State your answer clearly, boldly, and legibly, including units and a reasonable indication of precision. Assume that someone is challenging your answer, and prepare to **defend** it in terms of the sign, magnitude, and units of the answer. Go back over the logic of your solution, the mathematical operations involved, and the numerical calculations.

Identify the Principles **Illustrated**: Instructors assign problems to help you learn concepts, principles, and/or skills. Go back over the statement of the problem and the path you followed to the solution to **identify** the concept or principle or skill it was designed to **illustrate**.

Try a Different **Tactic**: See if you can find a different way of attacking and solving the problem. During the Evaluation and Exploration stage, you often think of several different routes or **tactics** you may take to reach a solution. Go back and **try** one or more of those. If it leads to a different answer, go back over both solutions to locate the flaw. If the two paths lead to the same answer, decide which is the cleaner, more direct path in terms of the principles and concepts involved.

If today is Friday, what day of the week will it be four days after yesterday?

To many people, this problem appears so easy that they think they should be able to answer it without even thinking!! Some may make a (slightly educated) guess. Others may have counted on their fingers or poked their finger at the days on an imaginary calendar. Some may even have created a makeshift calendar by writing the days of the week on a scrap of paper and marking them off to arrive at an answer. A few will have mentally performed some or all of these operations, arriving at the answer without any physical movement whatsoever.

While the problem may appear easy, the answer is not immediately obvious. You have to go through some thought processes to come up with the answer. This may be a light workout for your mental muscles, but it is exercise and practice so that you can go on to greater challenges. It also lets you look at the problem - solving tactics you are presently using and to compare them to a formal strategy.

If today is Friday, what day of the week will it be four days after yesterday?

Read and Re-state:
This problem clearly requires careful reading. You must pay close attention to the words today, yesterday, and after. You must think about what it says - If today is Friday - so we'll just pretend that today is Friday. Then it mentions yesterday, so that would have been Thursday. Now we've got to figure out what day comes four days after Thursday.

Evaluate and Explore:
This problem is stated simply in a straightforward manner, so there isn't a great deal to explore. It is clear that the answer must be based on the sequence of days in the week:

Sunday Monday Tuesday Wednesday Thursday Friday Saturday

If you can hold this sequence in your head while working on the problem, that's great. However, if you find anything awkward or confusing about it, make a note on a piece of scrap paper. Unless you're specifically told NOT to do this, it's perfectly OK.

S M T W Th F Sat

Making notes of information and/or making a sketch of the situation that the problem is addressing is an excellent tactic in starting to solve a problem. It helps you organize your concept of the problem, which will form the basis for your solution. It often makes you go back and read the problem more carefully.

Arrange and Attack:
You may be able to work directly from the note above, wrapping around from Saturday to Sunday or (in a different problem) from Sunday back to Saturday, but there's nothing wrong with writing the days of the week in a more convenient manner. Since we want to count forward from yesterday (Thursday), let's start the sequence on Thursday:

Th F Sat Sun M T W

Do it and Defend your answer:
Now the problem is simply a matter of counting days:

Th	**F**	**Sat**	**Sun**	**M**	**T**	**W**
yesterday	**today**					
	1	**2**	**3**	**4**		

So the answer is

********* Monday *******.**

Identify the Principles Illustrated:
The obvious principle of this problem is the sequence of days in the week. Since this discussion is about problem - solving, there are other principles involved: careful reading, translating the words into a thought process, defining a route to the solution, etc. If you have correctly identified the principles involved, you should be able to construct a similar problem based on these principles. Maybe,

If today is Sunday, what day of the week was it two days before tomorrow?

or perhaps something even more complicated.

Try a Different Tactic:
If you made a note and worked the problem on a piece of scrap paper, try starting over and working it in your head, just to build up some muscles there. If you worked it in your head, write the notes and check your work. The big advantage of the notes is that they give you a basis to check your work, and if you've made a mistake there is a possibility for someone to show you where you've gone wrong. A very good device here is to think of how you would explain to someone else how the solution was worked out.

Here's a problem to consider:

If the time is now 8:45 Tuesday evening, what will be the time in 6 hours and 30 minutes?

____ : ____ ____ _____
hour minute AM/PM weekday

Solve the problem to your own satisfaction, then think about how you arrived at that answer before clicking on continue.

If the time is now 8:45 Tuesday evening, what will be the time in 6 hours and 30 minutes?

____ : ____ ____ _____
hour minute AM/PM weekday

Read and Re-state:
All problems must be read carefully. This one states that the time is now 8:45 PM. It asks what the time will be in 6 hours and 30 minutes. This then seems to be a problem of adding time.

Before leaving this step, you should pay special attention to how you are expected to state your answer:

hour, minute, AM or PM, weekday.

Evaluate and Explore:
What is it that makes this problem difficult? If it asked us to add 1 hour and 10 minutes, the answer would be obvious. The problem is that we can't add time like ordinary numbers - minutes add up to :59, then the next minute is :00 in the next hour. Hours add up to 12:, then the next hour is 1:, and we change from AM to PM or from PM to AM.

Troublesome thought: Is midnight 12:00 AM or 12:00 PM? Does midnight Tuesday come before or after noon Tuesday?

Proper Response: That's interesting, but not relevant to solving THIS problem. I'll try to remember to think about it later.

Arrange and Attack:
Make some notes:

time now: **8 : 45 PM**
time to add: **6 30**

One way to attack this is to add the minutes, then the hours. If the minutes add up to 60 or more, the hour and the minutes will have to be re-set. Then if the hours add up to 12 or more, it will be the next day and the hour and AM/PM will have to be re-set.

Do it and Defend your answer:

Carry out the calculation in parts:

time now: **8 : 45 PM Tuesday**
time to add: **30**

new time: **9 : 15 PM Tuesday**
time to add: **6**

new time: **15 : 15 ? ? This is confusing.**

Go back to:
time now: **8 : 45 PM Tuesday**
time to add: **30**

new time: **9 : 15 PM Tuesday**
time to add: **3** **This will get us to midnight, and there are 3 hours left over.**

new time: **12 : 15 AM Wednesday**
now add: **3**

new time: **3 : 15 AM Wednesday**

Identify the Principles Illustrated:

The principle was properly identified in the Evaluate and Explore step - it's a problem of adding hours and minutes.

Try a Different Tactic:
Go back to the step above where it became confusing. The new time was 15:15 Tuesday(?) evening(?). When the hour went past 12, it became Wednesday morning and the hours started over so the hour is now (15 - 12 = 3) 3, and the time is 3:15 AM Wednesday.