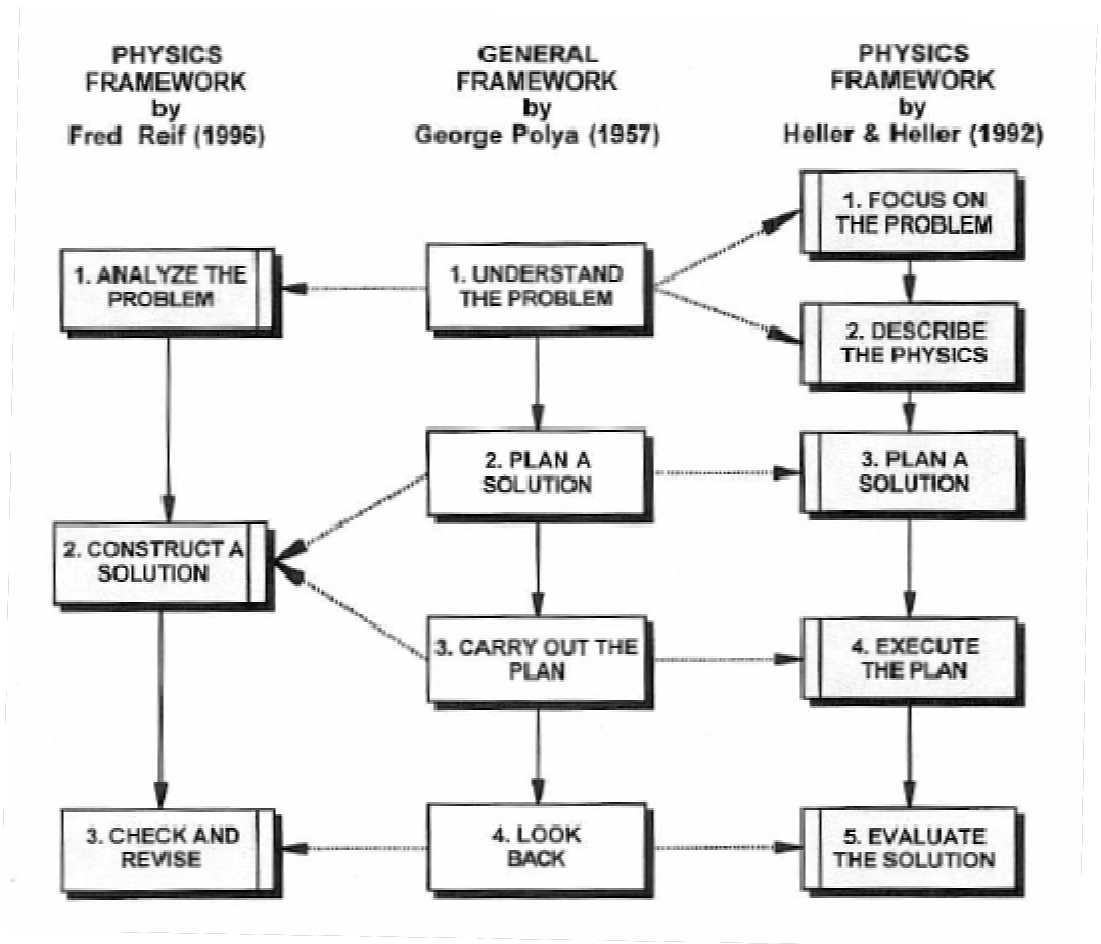
Designing a Problem-solving Framework

You learned in your reading that several research-based problem-solving frameworks for introductory physics have been developed and successfully used. These frameworks divide the important actions into a different number of steps and sub-steps, describe the same actions in different ways, and emphasize different heuristics depending on the backgrounds and needs of population of students for whom they were developed.



GROUP TASK:

The purpose of this task is for you to design a simple, one page problem-solving flow chart that you can have your students use. The flow chart will have **only three steps**, and **not include the last step** (Check and Revise, Look Back, or Evaluate the Solution).

1. Review the flow chart (expert) you made in activity 2. Also look at the problem solving steps by Fred Reif and from two textbooks (next two pages).

2. Decide which actions you think students should make in each step. Describe these actions on the Activity #8 Answer Sheet.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

One member from your group will be randomly selected to present your group's flow chart to the class

PRODUCT:

Activity 8 Flow Chart and Description for Students

The problem-solving framework by Frederick Reif for a calculus-based course.

1. **Analyze the Problem**: Bring the problem into a form facilitating its subsequent solution.
   - Basic Description – clearly specify the problem by
     - describing the *situation*, summarizing by drawing diagram(s) accompanied by some words, and by introducing useful symbols; and
     - specifying compactly the *goal(s)* of the problem (wanted unknowns, symbolically or numerically.)
   - Refined Description – analyze the problem further by
     - specifying the *time sequence* of events (e.g., by visualizing the motion of the objects as they might be observed in successive movie frames, and identifying the *time intervals* where the description of the situation is distinctly different (e.g., where acceleration of the object is different); and
     - describing the situation in terms of important *physics concepts* (e.g., by specifying information about velocity, acceleration, forces, etc.).

2. **Construct a Solution**: Solve simpler sub-problems repeatedly until the original problem has been solved:
   - Choose sub-problems by
     - examining the *status* of the problem at any stage by identifying the available known and unknown information, and the obstacles hindering a solution;
     - identifying available *options* for sub-problems that can help overcome the obstacles; and
     - selecting a useful sub-problem among these options.
   - If the obstacle is lack of useful information, then apply a *basic relation* (from general physics knowledge, such as $ma = F_{TOT}$, $f_k = \mu N$, $x = (1/2)a_x t^2$) to some *object or system* at some *time* (or between some times) along some *direction*. Eliminate the unwanted quantity by combining two (or more) relations containing this quantity.

   Note: Keep track of wanted unknowns (underlined twice) and unwanted unknowns (underlined once).

3. **Check and Revise**: A solution is rarely free of errors and should be regarded as provisional until checked and appropriately revised.
   - Goals attained? Has all wanted information been found?
   - Well-specified? Are answers expressed in terms of known quantities? Are units specified? Are both magnitudes and directions of vectors specified?
   - Self-consistent? Are units in equations consistent? Are signs (or directions) on both sides of an equation consistent?
   - Consistent with other known information? Are values sensible (e.g., consistent with known magnitudes)? Are answers consistent with special cases (e.g., with extreme or especially simple cases)? Are answers consistent with known dependence (e.g., with knowledge of how quantities increase or decrease)?
   - Optimal? Are answers and solutions as clear and simple as possible? Is answer a general algebraic expression rather than a mere number?

Problem Solving Steps from a Textbook

The following is applicable to all types of problems.

1. Begin by drawing a neat diagram that includes the important features of the problem.
2. Choose a convenient coordinate system and indicate it on your diagram. Show the origin and positive directions. When possible, choose the origin to be on the particle at t = 0 so that $x_o = 0$.
3. Show known quantities on your diagram.
4. When possible, write an equation for the quantity to be found in terms of other quantities that are known or can be found. Then proceed to find the other quantities in your equation.
5. When possible, solve the problem two different ways to check your solution.
6. Examine your answer to see if it is reasonable.

Problem Solving Steps from Another Textbook

<u>Gather Information</u>

The first thing to do when approaching a problem is to understand the situation. Carefully read the problem statement, looking for key phrases like "at rest" or "freely falling." What information is given? Exactly what is the question asking? Don't forget to gather information from your own experience and common sense. What should a reasonable answer look like? You wouldn't expect to calculate the speed of an automobile to be 5×10^6 m/s. Do you know what units to expect? Are there any limiting cases you should consider? What happens when an angle approaches 0^o or 90^o or when the mass becomes huge or goes to zero? Also make sure you carefully study any drawings that accompany the problem.

<u>Organize Your Approach</u>

Once you have a really good idea of what the problem is about, you need to think about what to do next. Have you seen this type of question before? Being able to classify a problem can make it easier to lay out a plan to solve it. You should almost always make a quick drawing of the situation. Label important events with circled letters. Indicate any known values, perhaps in a table or directly on the sketch.

<u>Analyze the Problem</u>

Because you have already categorized the problem, it should not be too difficult to select relevant equations that apply to this type of situation. Use algebra (and calculus, if necessary) to solve for the unknown variable in terms of what is given. Substitute in the appropriate numbers, calculate the result, and round to the proper number of significant figures.

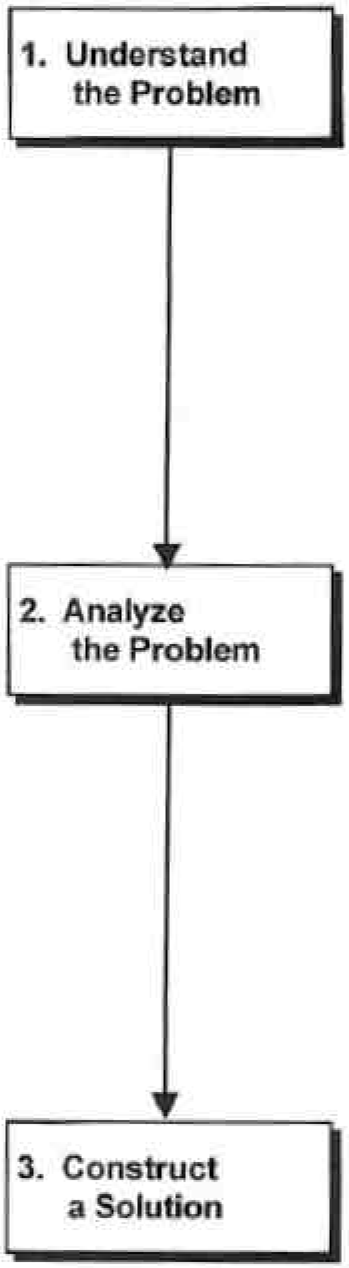
<u>Learn from Your Efforts</u>

This is the most important part. Examine your numerical answer. Does it meet your expectations from the first step? What about the algebraic form of the result – before you plugged in numbers? Does it make sense? (Try looking at the variables within it to see whether the answer would change the answer in a physically meaningful way if they were drastically increased or decreased or even became zero.) Think about how this problem compares with others you have done. How was it similar? In what critical ways did it differ? Why was this problem assigned? You should have learned something by doing it. Can you figure out what?

TA Orientation 2006
Activity 8

Manager:____________________________
Recorder:____________________________
Skeptic:____________________________
Summarizer:___________________________

Description for Students



Calvin and Hobbes / By,Bill Watterson

Design an Answer Sheet for your Students

You learned in the reading that it is helpful to provide students with answer sheets during the first 3-6 weeks of the course. Answer sheets provide students with cues for the major steps of your problem-solving framework.

GROUP TASK:

1. Review the answer sheets in the Competent Problem Solver.
2. Decide what cues you want to provide on the answer sheets for your students. Write these cues on the Activity #9 Answer Sheet.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

One member from your group will be randomly selected to present your group's answer sheet to the class

PRODUCT:

Activity 8 Answer Sheet

Answer Sheet

UNDERSTAND THE PROBLEM
ANALYZE THE PROBLEM
CONSTRUCT A SOLUTION

SAMPLE ANSWER SHEET:

Manager: ______________________________

Recorder: ______________________________

Skeptic: ______________________________

Skeptic: ______________________________

Course:_________ Section: _________

Date: __________

UNDERSTAND THE PROBLEM
Picture and Given Information

Question:

Physics Concepts:

Approximations and Constraints:

ANALYZE THE PROBLEM
Diagram and Define Quantities

Target Quantity:

Useful Equations:

CONSTRUCT A SOLUTION

Construct specific equations, eliminate unwanted unknowns, and solve for target quantity.

Check Units:

Calculate Numerical Answer

SAMPLE ANSWER SHEET:

FOCUS the PROBLEM Picture and Given Information

Question(s)

Approach

DESCRIBE the PHYSICS
Diagram(s) and Define Quantities

Target Quantity(ies)

Quantitative Relationships

PLAN the SOLUTION

Construct Specific Equations

Check Units

EXECUTE the PLAN

Calculate Target Quantity(ies)

EVALUATE the ANSWER

Is Answer Properly Stated?

Is Answer Unreasonable?

Is Answer Complete?

(extra space if needed)