PROBLEM SOLVING STRATEGIES

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Two factors can help make you a better physics problem solver. **First of all, you must know and understand the principles of physics. Secondly, you must have a strategy for applying these principles to new situations in which physics can be helpful.** *Many students say, "I understand the material, I just can't do the problems." If this is true of you as a physics student, then maybe you need to develop your problem-solving skills.* Having a strategy to organize those skills can help you.

Physics problem solving can be learned just like you learned to drive a car, play a musical instrument, or ride a bike. What can aid you more than anything is to have a general approach to follow with each problem you encounter. *You may use different tools or tactics with differing areas of physics, but the overall strategy remains the same.* Most likely, you have already acquired some problem-solving skills and habits from previous courses in physics, chemistry, or mathematics. Like other areas of learning and life, some of these habits may be beneficial and some may actually hinder your progress in learning how to solve physics problems.

So, in learning this new approach, be willing to try new ideas and to discard old habits that may in fact be hindering your understanding. As you mature as a physics problem solver, you will find that the approach will become second nature to you. You will begin automatically to do those things that will lead you to construct an effective solution to the problem.

As with so many other learning activities, it is useful to break a problem solving strategy into major and minor steps. The strategy we would like you to learn has five major steps: *Focus on the Problem*, *Physics Description*, *Plan a Solution*, *Execute the Plan*, and *Evaluate the Solution*. Let's take a detailed look at each of these steps and then do a sample problem following the strategy. At this stage of our discussion, do not worry if there are physics terms or concepts that you do not understand. You will learn these concepts as they are needed. Then, refer back to this discussion.

1. FOCUS on the PROBLEM

Usually when you read the statement of a physics problem, you must visualize the objects involved and their context. You need to draw a picture and document the given information.

- First, construct a mental image of the problem situation.
- Next draw a rough, although literal, picture showing the important objects, their motion, and their interactions. An interaction, for example, may consist of one object being connected to another by a rope.
- Label all known information. At this point, do not worry about assigning algebraic symbols to specific quantities.

Sometimes the question being asked in the problem is not obvious. “Is the rope safe?” is not something you can directly answer. Ask yourself, what specifically is being asked? How does this translate into some calculable quantity?

There are many ways to solve a physics problem. One part of learning how to solve a problem is to know what principles of physics to use in your approach. You will need to determine the concepts and principles you think will be useful in solving the problem.

- If simple motions are involved, use the kinematics definition of velocity and acceleration. Decide if there is constant velocity or constant acceleration.
- If forces are involved and objects interact due to these forces, use Newton's Laws of Motion and relate acceleration to the changes in the motion.
- Forces that act over a time interval and cause objects to change their velocities suggests using the Conservation of Momentum.
- Frequently in situations involving thermal physics or electromagnetism, the principle of Conservation of Energy is useful.
- You may need to specify time intervals or distances over which the application of each principle will be the most useful.
- It is important to identify any constraints present in this situation, such as "the car doesn’t skid."

- Specify any approximations or simplifications you think will make the problem solution easier, but will not affect the result significantly. Frequently we ignore frictional forces due to air resistance.

Your approach probably will be very consistent throughout a particular section of the textbook. The challenge for you will be to apply the approach in a variety of situations.

2. DESCRIBE the PHYSICS

A "physics description" of a problem translates the given information and a very literal picture into an idealized diagram and defines variables that can be manipulated to calculate desired quantities. In a sense, you are translating the literal situation into an idealized situation where you can then apply the laws the physics. That is, you are making a model that can be solved. **The biggest shortcoming of beginning physics problem solvers is attempting to apply the laws of physics, that is write down equations, before undertaking this qualitative analysis of the problem.** If you can resist the temptation to look for equations too early in your problem solution, you will become a much more effective problem solver.

To construct your physics description, you must do the following:

- Translate your literal picture into an abstract diagram(s) (make a model) which gives only the essential information for a mathematical solution. In an idealized diagram, people, cars, and other objects may become square blocks or points.
- Define a symbol for every important physics variable on your diagram. Improper or incomplete variable definitions can lead to disastrous results.
- Usually you need to draw a coordinate system showing the + and - directions.
- If you are using kinematics concepts, draw a motion diagram specifying the objects' velocity and acceleration at definite positions and times. In general it is best to take the direction of initial motion as the + direction.
- If interactions are important, draw free body diagrams.
- When using conservation principles, draw "before", "transfer" (i.e., during), and "after" diagrams to show how the system changes.
- To the side of your diagram(s), give the value for each physics variable you have labeled on the diagram(s) or specify that it is unknown.

Then, using the question, your physics description, and the approach you have stated, you will need to identify a target variable. That is, you must decide what unknown quantity it is that you must calculate from your list of variables. Ask yourself if the calculated quantity answers the question. **In complex problems there may be more than one target variable or some intermediate variables you will calculate.**

Now, knowing the target variable(s) and your approach, you can assemble your toolbox of mathematical expressions using the principles and constraints to relate the physics variables from your diagrams. This is the first time you really begin to look for quantitative relationships among the variables. **You are simply constructing a mathematical model of the physical situation you have described in the diagrams.**

3. PLAN the SOLUTION

Before you actually begin to calculate an answer, take time to make a plan. Usually when the laws of physics are expressed in an equation, the equation is a general, universal statement. You must construct specific algebraic equations that will enable you to calculate the target variable.

- Determine how the equations in your toolbox can be combined to find your target variable.
- Begin with an equation containing the target variable.
- Identify any unknowns in that equation.
- Find equations from your toolbox containing these unknowns.
- Continue this process until your equations contain no new unknowns.
- Number each equation for easy reference.
- Do not solve equations numerically at this time.

You have a solution if you have as many independent equations as there are unknowns. If not, determine other equations or check the plan to see if it is likely that a variable will cancel from your equations.

If you have the same number of equations and unknowns, indicate the order in which to solve the equations algebraically for the target variable. Typically, you begin your construction of the plan at the end and work backwards to the first step, That is, you write down the equation containing the target variable first.

4. EXECUTE the PLAN

Now you are ready to execute the plan.

- Do the algebra in the order given by your outline.
- When you are done you should have a single equation with your target variable isolated on one side and only known quantities on the other side.
- Substitute the values (numbers with units) into this final equation. A major shortcoming of beginning problem solvers is inserting numbers much too early in the solution of a problem.
- Make sure units are consistent so that they will cancel properly.

Finally, calculate the numerical result for the target variable(s). Make sure your final answer is clear to the person who will evaluate your solution.

It is extremely important to solve the problem algebraically before inserting any numerical values. Some unknown quantities may cancel out and you won't need to actually know their numerical value. In some complex problems it can be useful to calculate intermediate numerical results as a check on the reasonableness of your solution.

5. EVALUATE the SOLUTION

Finally, you are ready to evaluate your answer. Here, you must use your common sense about how the real world works **as well as** those aspects of the physical world you have learned in your physics class.

- Do vector quantities have both magnitude and direction?
- Can someone else follow your solution?
- Is the result reasonable and within your experience? Remember, for example, that cars don't travel down the highway at 300 mi/hr. If you put a cooler object into hot water, the water cools down and the object rises in temperature.
- Do the units make sense? Velocity is not measured, for example, in kg/s.
- Have you answered the question?

Whenever possible, it is a good idea to read through the solution carefully, especially if it is being evaluated by your instructor. If your evaluation suggests to you that your answer is incorrect or unreasonable, make a statement to that effect and explain your reasoning.

The problem solving strategy outlined above can be generalized into the three steps used in the following articles: e.g. "Heuvelen, A. V. (1991), Johnson, M. (2001), Reif, F. and Scott, L .A. (1999), Leonard, W. J., Dufrense, R. J. and Mestre, J. P. (1996).

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