Problem Solving

General techniques

Introduction

You can't solve problems well unless you understand three things.
1) what information is given in the problem statement
2) what you are being asked to find
3) what physical principles permit a solution
What follows is a general template you should use to ensure you have these three things in hand before attempting a solution. While it may seem cumbersome for simple problems, we'll use this template all semester. Practicing now will help you find success when more involved concepts and problems present themselves

Template

Given information

The first step is to identify given information. At this point you should also start naming the information. For instance, when a problem indicates something like "A ball is released from rest at height 3m," you can write two things. First, that the initial velocity, $V_0 = 0 \, \frac{m}{s}$ and also that the initial height is 3m. You may wish to call this h_0, x_1, y_i, etc. depending on the problem and how you think about it. That decision is intimately tied to the second step, and as you gain experience, you'll be able to anticipate naming before even doing the sketch. For now, you should do these first two steps simultaneously.

Free Body Diagram / Sketch

This helps you visualize the problem and identify forces acting on things. The first step is to choose a coordinate system. This is a fancy term for essentially deciding where the origin is and which direction(s) is positive. The second part is representing the problem on this coordinate system. Include bodies, acceleration, velocity, etc. The key is to develop a standard that works for you to help you identify missing information. Here are two possibilities for the above example:
1) the origin is placed where the particle lands and the positive direction is up
2) the origin is placed at the point of release, and the positive direction is down

Interplay

This is the part that usually hangs people up. Once you have the given information collected and represented on the sketch, it's time to decide what's not given. In the example above, there is no information explicitely given about the ball's final state. We know it was released from rest at a given height, but that's it. However, we know some things that are not said. First, there is a constant accelera-

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tion due to the force of gravity. We also know, based on our choice of coordinate system, what the final position is. Keep going back and forth between the sketch and given info until you are sure that there is no more information available to you from the problem specification.

What to find

Is there a specific quantity requested in the problem specification?

Problem type / Physical principles / Equations

Identify the type of problem you are asked to solve. Is it motion in one dimension, two dimensions, work-energy theorem? This will define what physical principles are in play and in turn, which equations are appropriate to use.

You want to come up with an equation that can be solved for the quantity requested in the problem statement, but you must understand which equations are appropriate before making the selection. For problems like the example, you have only three kinematic equations from which to choose. In the future there will be many more, but even for something like this, you can save a bunch of time by making an informed decision before getting out your calculator. For simple kinematic problems you use one equation to solve for one variable. In slightly more complicated problems, you'll solve one equation to get an intermediate quantity that you use to solve another equation. This is why you must know where you're going before you try to go there and why it is good policy to keep your equations symbolic as long as possible. While setting up each problem, the last line should be a map of your eventual solution. ie. "Use $x = x_0 + v_0 t + \frac{1}{2} a t^2$ to obtain t" The kinematic equations are below in the next section for reference.

Solution

Now you have a plan but implementing it is more than just punching numbers on a calculator. Frequently it will be hard to see the entire expression you've put into your calculator. In homework exercises, you have the opportunity to double or triple-check these things. On a test you don't have this luxury. This "Solution" step is designed to minimize silly errors.

Make A Guess

Before crunching numbers, make a guess about the solution. You know what you're looking for from the "What to find" section of this template, and your plan should finish with an equation or system you'll solve for some variable. Does that variable make sense? What are the typical units of that variable? What are the typical units of your "What to find?" Does the problem specify a required unit?

Implement solution plan

Crunch the numbers in this format:

1) write the equation or system symbolically (no numbers unless they're in the equation, like $\frac{1}{2}$, 2, π, etc.

2) write the equation with only numbers (no symbols or units). Replace every quantity in step one for which you have a number, calculate and write the raw answer without units. Don't bother with significant figures yet.

3) write the equation with only units. Dimensionless quantities like pi or $\frac{1}{2}$ should be excluded. Solve

this out to obtain the unit of your answer.
4) report the answer: (variable = number & unit)

If you need to convert the unit, you can do it now. With practice, you'll gain a feel for how things interact and be able to anticipate doing conversions before you start, but it is frequently easier to worry about this as a last step. Use the picket fence method. Little is more disappointing on an exam or homework than getting the physics right and still losing points on something so elementary as unit conversions.

Kinematic Equations

$x = x_0 + v_0 t + \frac{1}{2} a t^2$

$v = v_0 + a t$

$v^2 = v_0^2 + 2 a (x - x_0)$