Preparation for Problem Solving IV
Kinematics Problem Analysis

We have previously discussed and practiced problem analysis for geometric problems. The steps we learned were general and can be applied to many types of problems. Now, we will discuss and practice the application of these steps to solving kinematics problems.

Recall that problem analysis consists of a set of steps (guidelines) you need to follow in order to have a clear "picture" of the problem. Here are the steps we used previously.

(1) Read the problem from start to finish. You will refer back to the problem as necessary.

(2) Draw a picture or diagram of the problem, if possible.

With kinematics problems this should always be possible.
Also, with kinematics problems, you should always draw each moving object in the problem showing both its starting and ending location. In some cases, you will draw the object at more instants like frames of a comic strip. We will refer to these drawings as freeze frames. Making freeze frame drawings can be a useful tool in solving problems in which more than one object move.

(3) Ask yourself two questions:
What quantities are given or implied? (What are the knowns?)
What is it that the problem wants you to find? (What are the unknowns?)

(4) Assign a symbol (letter) to each quantity. Make sure different symbols are assigned to different quantities. If you have a diagram, label the quantities in your diagram with the symbols.

With kinematics you will have six quantities for each object for each stage of its motion, they are initial and final position, initial and final velocity, time, and acceleration. You should use the symbols x_i (or x_0), x_f (or x), v_i (or v_0), v_f (or v), t, and a respectively.
If you have a problem with more than one object, say Kathy and Chris are each driving a car in a problem, use subscripts for each object, K for Kathy and C for Chris. So, v_{K0} would be Kathy's initial velocity and a_C would be Chris's acceleration.
If an object moves for one time interval with one acceleration and then for a second time interval with a different acceleration, subscripts should also be used to indicate which time interval you are working with. The acceleration during the first time interval or "stage" may be $a_1 = 2.0\ m/s^2$. The second stage may last for $\Delta t_2 = 5.0$ s.

(5) Think about what principles, definitions and/or concepts are important in the problem and list them. Things like: "the area of a triangle" or "the definition of average velocity".

For kinematics problems these will be from a set of equations of motion for each stage of each object's motion.

The equations of motion can be used in either of the following forms. The second is more common in physics textbooks at the college level.

$$(0)\quad x_f = x_i + \tfrac{1}{2}(v_i + v_f)t \qquad (2)\quad v_f = v_i + a\,t$$
$$(1)\quad x_f = x_i + v_i\,t + \tfrac{1}{2}a\,t^2 \qquad (3)\quad v_f^2 = v_i^2 + 2a\,(x_f - x_i)$$

Or

$$(0)\quad x = x_0 + \tfrac{1}{2}(v_0 + v)t \qquad (2)\quad v = v_0 + a\,t$$
$$(1)\quad x = x_0 + v_0\,t + \tfrac{1}{2}a\,t^2 \qquad (3)\quad v^2 = v_0^2 + 2a\,(x - x_0)$$

There are several types of kinematics problems:

A. One Object, One Stage Problems:

This type of problem involves a single object that undergoes a constant acceleration for the entire period of interest. These problems are solved by setting up the appropriate equation(s) for this single object and solving for the specified unknown(s).

B. One Object, Multiple Stages Problems:

A second type of problem involves a single object that undergoes motion with an acceleration that is not constant for the entire period of interest. If this motion consists of a series of time intervals during which the acceleration is constant, we can set up and solve the appropriate equation(s) for each time interval (stage) of the motion. The final conditions (position, velocity, and time) for one stage serve as the initial conditions for the next stage.

C. Problems with Two or More Objects:

A third type of problem involves more than one object, each of which undergoes a constant acceleration for one or more stages. Typically, the two objects have different accelerations but there is some relationship between their motions that is desired (for example, at some specific time the two objects are at the same position). These problems can be solved by setting up the appropriate equations for each object and using the desired relationship to solve for the unknown quantities.

The following three examples will be done in class. You will be asked to do part of them and your instructor will go over each part.

Example A: You are driving a car at 30.0 mph when you begin to apply the brakes. Your car stops after travelling 152 ft. What acceleration (assumed constant) did the car have while you were applying the brakes?

Example B: A model rocket is launched from the ground. It starts from rest and accelerates upward at 15.0 m/s^2 for 3.00 s. Then, it has a downward acceleration of 9.80 m/s^2 until it reaches its highest point. What is the highest above the ground that the rocket gets?

Example C: Sheila leaves her home to walk to school at 7:30 am. After she leaves, her father notices she has forgotten her lunch. He walks outside and calls to her, but Sheila is listening to music through headphones and does not hear her father. Her father starts walking after her. He walks at 6ft/s. Sheila is walking at 4 ft/s. If Sheila is 60 ft in front of her father when he begins his pursuit, how far will her father walk before catching up to her?

Now, like everything in physics, you'll need to practice. Follow each of the five steps outlined above to analyze these Exercises. Do NOT solve them!

Exercise 1: A small airplane has a lift-off speed of 120 km/h. What minimum constant acceleration does this require if the airplane is to lift off before reaching the end of a 240-meter runway?

Exercise 2: A bullet is fired through a board 10.0 cm thick in such a way that the bullet's line of motion is perpendicular to the face of the board. The initial speed of the bullet (as it enters the board) is 24.0 km/min and it emerges from the other side of the board with a speed of 18.0 m/min. Find the acceleration of the bullet as it passes through the board.

Exercise 3: A car starts from rest and travels for 5.0 s with a uniform acceleration of + 1.5 m/s^2. The driver then applies the brakes, causing a uniform acceleration of -2.0 m/s^2. If the brakes are applied for 3.0 s, how fast is the car going at the end of the braking period, and how far has it gone?

Exercise 4: Runner A is initially 4.0 mi west of a flagpole and is running with a constant velocity of 6.0 mi/h due east. Runner B is initially 3.0 mi east of the flagpole and is running with a constant velocity of 5.0 mi/h due west. How far are the runners from the flagpole when their paths cross?