Group Problem Set 4: Kinematics and Problem Solving

Right about now, problems have started to look more complicated. There are two (2) ways to handle more complex physics problems:

1. Cry.
2. Follow the guide to problem solving and break complex problems into manageable steps with regulatory components that function as a self check to ensure you are doing it right.

You will find much more success with homework and on exams, should you choose to follow the second methodology to physics problem solving. The most complex problems can be broken down into very manageable steps, but don't feel like you can only use these problem solving steps for complex kinematics problems. Feel free to practice the following steps on other problems too.

1. **Draw a picture.** Start by sketching the problem. Draw the moving object at the various locations provided. Sometimes the location won't be explicitly stated and you will have to infer where the particle is (i.e. on the ground). Problem sketches don't need to be detailed or perfect. Sticks and boxes can easily take the place of more complex structures. You don't need to spend an excessive amount of time drawing the situation outlined in the problem. The goal here is to create a visual of the problem to make assigning characteristics (velocity, distance and acceleration) easier. Simple clear graphical sketches will go a long way in clearing up much of the confusion that comes with word problems.

2. **Assign a coordinate system.** Assign the coordinate system that makes the most sense for the problem. Include directions and units when possible. It helps here to assign the coordinates such that most of the motion is positive. Carrying around minus (-) signs will just clutter the diagram and they have a way of getting lost in equations!

3. **Label velocity and time.** When possible, label the velocity and time for each location. These values may not correspond to numbers and may be just place holders (i.e. v_1). Velocities and times may not be explicitly stated. If a ball is dropped from a window, you can assume that the time started when the ball was dropped and it will accelerate (have a +v) because it started from rest. You can assume that when an object 'stops' or 'comes to rest' (another favored physicists' turn of phrase) that the velocity here is also 0. **Make sure your velocity has the appropriate direction (sign) in your coordinate system.** (See problem 1)

4. **Label acceleration where possible.** Once you have the velocities and times in, you should easily be able to label accelerations between positions.

5. **Identify the quantity asked for and write down the relevant equations required to find it.** Now that you know everything about the motion of the system you were given, it should be a lot less daunting to look at what you are asked for and find the equations necessary to solve the problem. There may be times where you have to choose between two equations and knowing what you know (from steps 1-4) will help you to decide which equation is easier to use.

6. **Evaluate the problem and assess if your answer is logical.** Plug in the appropriate values to the formula identified in step 5. Make sure to keep track of all of your signs and units. Now consider your answer. Does it makes sense? Would you expect a ball dropped from a tall building to have a higher velocity at the top of the building or the bottom?

Kinematic Equations for Constant Acceleration

Given a constant acceleration, we can use several equations to determine velocity, position or time of a particle's motion. These equations represent motion in one dimension but, as we will see later, they can be generalized for 2 or 3 dimensional motion.

$$v_f(x) = a_x t + v_{ox} \tag{1}$$

$$\Delta x = \frac{1}{2}(v_{0x} + v_x)t \tag{2}$$

$$\Delta x = v_{ox} t + \frac{1}{2} a_x t^2 \tag{3}$$

$$\Delta x = v_x t - \frac{1}{2} a_x t^2 \tag{4}$$

$${v_x}^2 = {v_{0x}}^2 + 2a_x \Delta x \tag{5}$$

1. **CONCEPTUAL:** Two balls are dropped from your dormitory. Ball A is dropped from the second story window and ball B is dropped from the roof (twice the height of ball A). Assuming these balls fall to the ground with the same acceleration, will their final velocities be the same? Why or why not? Explain your answer. **ANSWER IN WORDS ONLY**

2. **CONCEPTUAL:** Two cars drag race starting from rest. Car A travels twice the distance of Car B after a certain amount of time. What is car A's acceleration with respect to car B's? What is car A's velocity with respect to car B's? **ANSWER IN WORDS ONLY**

3. In mountainous regions, steep ramps are built off the side of the road and are used as emergency braking areas to prevent large scale collisions. Obtain a marble track and use it as a model to study these braking systems.

   (a) Using your phone, make a video of the marble, starting from rest on the highest track, travelling down to the base of the track and then back up to a lower track on the opposite side (you get to choose which you use). You will use the time stamps in the video to determine the travel time for each portion of this problem.

   (b) Measure the time in seconds to send a ball from rest at the top of the tallest track to the bottom of the track.

   (c) The track length is approximately 26 cm. What is the velocity at the base of the track?

   (d) What is the acceleration of the marble over this distance?

   (e) Now, using the video from above, find the time it takes for the marble to travel from the base of the first track to the top of the second track.

   (f) Using this second time interval and the velocity at the base of the track found above, what is the acceleration for this portion of the marble's trip? What assumptions are you making to find this?

   (g) How far does your marble travel along this new track before stopping?

   (h) Do your accelerations measured for the beginning and the end of the trip match? Why or why not?

   The marble decelerates as it reaches the top of the track. It then changes trajectory, reversing course and returns to the base between the tracks.

   (i) Using the time stamp in the video and distance just calculated, what is the acceleration of the marble as it returns back down the track?

   (j) What is the acceleration of the marble right when it stops and turns around?

   (k) Do your accelerations for the marble going up and down the second track match? why or why not?

   (l) Now, look at the other options for your second track. Based on your own experience, discuss what you think the behavior of the marble would be if it were to instead travel up either of the other two tracks. Be sure to discuss the changes in velocity, acceleration, path length and total distance travelled.

4. **EXTRA PRACTICE PROBLEM** Your instructor tries to shoot a basketball underhanded toward a basketball hoop (basketball is not her strong suit...). The ball travels straight up and touches the rim, but does not go in. It then free falls straight down to the ground and hits her foot. Assume that there is no air resistance.

   (a) The ball leaves her hand traveling 6.32 m/s and travels up 2 meters to the rim of the basket. How long does it take for the ball to reach the hoop?

   (b) Acceleration due to gravity is $10m/s^2$. How long does it take for the ball to hit the floor if the hoop is at standard height (3 m)?

   (c) What is the velocity of the ball right before the ball hits her foot (you can assume that her foot is at the same level as the ground)?

   (d) What is the total time the ball is in the air?

5. **EXTRA PRACTICE PROBLEM** Your instructor is convinced that if she stands on a 1m ladder while throwing a basketball, she will be able to get the basket in the basketball hoop. Your instructor again shoots a basketball underhanded toward a basketball hoop. The ball travels up, assuming no air resistance, and then free falls down into the basketball hoop and to the ground. Answer the following questions and show your work below.

   (a) The ball leaves your instructor's hand traveling upward at 6.32 m/s. The ball travels for 0.63 s before it comes to rest and starts to fall down. How far from your instructor's hand does the ball travel before it stops and changes directions?

   (b) Assuming that, including the ladder, the ball leaves your instructor's hand 2 meters from the ground, how far off the ground is the ball when it comes to rest before falling to the ground?

   (c) Given that the ball experiences free fall to the ground, what is the velocity of the ball when it hits the ground? How long does it take the ball to fall?

   (d) Is the final velocity of the ball when it hits the ground in problem (5) greater or smaller than the final velocity found in problem (4)? Does this make sense? Reference the equations required to rationalize this.