Homework 1

Due January 22, at the start of recitation

1. A person is standing in front of a second-story window that is a height h above the ground. Someone standing on the ground throws a snowball straight up; it goes up into the air, past their window, and then falls back to the ground. (Suppose that you call ground level $x = 0$ and the snowball's initial velocity v_0.)

   You can calculate lots of things about this situation. To do so, you'll need to frame your physics questions in terms of question-sentences about the quantities that appear in the equations of motion.

   In this problem, you won't actually calculate anything. Instead, write out sentences that allow you to answer the following. I'll do the first one for you.

   My experience teaching this class shows that *most students who don't do well on the first exam have trouble with this step.*

   (a) How long does it take before the snowball lands on the ground again? (*Answer: "What is the time at which the position equals zero?"*)

   (b) How high does the snowball go?

   (c) How much time does the snowball take to reach its highest point?

   (d) At what time does the snowball pass the person's window on the way up?

   (e) At what time does the snowball pass the person's window on the way down?

   (f) How fast is the snowball traveling when it passes the person's window on the way up?

   (g) How fast must the thrower throw the snowball so that it makes it to the window?

2. Parts (d) and (e) from the last problem seem to be asking for you to solve for the same thing: you're supposed to calculate the time at which something is true. This may seem a little odd: how can *one* equation have *two* different answers?

   Do you know a commonly-used algebraic formula that can produce two answers from one equation? What formula is that? Does it *always* produce two answers? If not, what might happen instead? How does this relate to part (g) of the previous problem?

3. A car driving from Tucson to Nogales is distracted by some physics students launching model rockets in the desert, veers off the road, and crashes into a cactus. The driver is luckily wearing their seatbelt, which causes them to decelerate from 100 km/hour to a dead stop in 50 milliseconds.

   In this problem, you will calculate the acceleration of the driver as their seatbelt brings them to a stop.

(a) There are some numerical quantities given to you in the problem: 110 km/hour and 50 milliseconds. When in the problem should you introduce those numerical values? What algebraic variables will you use to represent them?

(b) Write an expression that gives the velocity of the car $v(t)$ as a function of time t, in terms of the acceleration of the car a and the initial velocity v_0. What physical moment corresponds to the time $t = 0$?

(c) As we discussed in class, the key to solving kinematic problems is to rephrase them as a question in terms of your algebraic variables. This problem's question has the following form: "What is the value of _____ such that _____ is equal to zero at time _____?" Fill in the blanks.

(d) Write an algebraic statement that corresponds to the sentence you wrote, and solve it for the acceleration.

(e) Substitute in the given numerical values and find the acceleration. When you do this, make sure you retain *all* units: the initial velocity is not "110", but "110 km/hour".

(f) In this problem, you will have encountered some minus signs in your algebra. What is their physical significance?

4. In the previous problem, you solved for the acceleration of the driver. How many times greater is this acceleration than that of an object in free-fall? When making your comparison, remember to retain all units; you can manipulate them exactly as you do algebraic quantities.

5. In Tolkien's *Fellowship of the Ring*, Pippin foolishly throws a stone down a well in Moria, only to hear it splash seconds later as it hits the bottom. Tolkien doesn't tell us how long this takes, but Peter Jackson's film interpretation is on Youtube: `https://youtu.be/5cZ4ABUo6TU`

   Here the bucket slides off of the ledge at 0:30, and the last of the clattering sounds (presumably the bucket striking the bottom) happens at 0:44.

   You may assume that Middle-Earth has the same gravity as Earth.

   (a) Ignoring air resistance and the travel time of sound, how deep is the well?

   (b) Did you encounter any minus signs in your solution to this problem? If so, what is their physical meaning? If not, did you make any particular choices that kept all quantities positive?

Hint: Follow the same schematic as the first problem. Write down equations of motion for the bucket's position and/or velocity as a function of time; think of a sentence in terms of your algebraic variables that asks the correct question; then, apply that sentence to your equations of motion to determine the depth.

6. A bicyclist starts from a stop, accelerates at 1 m/s^2 for 6 seconds, travels at a constant velocity for 5 seconds, and then applies her brakes, decelerating at 2 m/s^2 until she comes to a stop again.

   (a) Make acceleration vs. time and velocity vs. time graphs for the cyclist. Be precise!

   (b) How far does she travel?

   (c) Now make a position vs. time graph for her. (Again, be precise!)

   Hint: You know some relations for constant-acceleration kinematics, but the acceleration is only constant during three separate intervals, not the entire problem. How can you deal with that? What are the initial position and velocity for the different intervals?

7. A driver is driving once again from Nogales to Tucson on I-19. Suddenly a roadrunner darts out into the middle of the road. It doesn't see her at first, because it is focused on a tasty lizard it's trying to catch. She is initially traveling at 110 km/hour, the roadrunner is 30m in front of her when she applies her brakes, and the brakes decelerate the car at 9 m/s^2.

   She slams on her brakes, and the sound of squealing brakes alerts the bird to the onrushing car. Being an agile critter, it hops out of the way, squawking irately that its meal has been disturbed.

   Hint: You will need the quadratic formula for this problem.

   (a) Graph the position vs. time of the car, and label the position of the roadrunner on the graph.

   (b) How long does the roadrunner have to get out of the car's way?

   (c) The quadratic formula gives you two solutions to the quadratic. Which one is the physically meaningful answer? What does the other solution mean, if anything?

   Hint for part c: You wrote down an expression for position vs. time for the car. What assumption did you make about the car's acceleration when you wrote down that expression? Is that assumption always valid? If not, in what interval of time is it valid?