Assignment III, HONS 157 (Honors Physics I)
Fall 2015
Due 9/11/15 at start of class

As always, please put your answers on separate paper. *Unless told otherwise, leave all answers in SI units!*

1. (This is a pretty famous question): Two cars are traveling towards each other – car one travels North at a speed of 15 m/s and car two travels South at a speed of 25 m/s (so the cars approach each other at 40 m/s). At time $t = 0$ the cars are a distance of 1600 meters apart. Also at time $t = 0$, a bird that flies 60 m/s (with respect to the ground) starts on the hood of one of the cars and flies to the hood of the other car. Then, after getting to the second car, the bird instantaneously turns around and flies back to the hood of the first car. Each time the bird reaches the hood of one of the cars, it turns around and flies towards the other car.

   a) How long after $t = 0$ does the bird fly until it gets squished between the cars?

   b) How far did the bird fly on his fateful trip? (Distance flown by the bird, not displacement).

2. Let us say that two unevenly matched athletes want to have a race. Athlete 1 (call her Abby) has a top speed of 7.3 m/s and has a top acceleration of 2.3 m/s^2. Athlete 2 (call her Beth) has a top speed of 8.7 m/s and has a top acceleration of 2.9 m/s^2. Clearly, Beth will win pretty much any race with Abby unless there's some sort of handicap. We'll design two systems. (Note – in all cases, assume that a racer accelerates at their top acceleration until they reach their top speed, then they run at their top speed steadily).

   a) Let's say that Abby and Beth want to run the 100 meter dash. To make it fair, Beth will give Abby a head start. How long of a head start should Beth give Abby so that they should finish at the same time?

   b) Instead of giving a head start, Beth now decides to let Abby run a shorter race than Beth. If Beth runs a full lap around the track (400 meters), how far down the track should Beth let Abby start so that Abby and Beth should have a photo finish?

3. You are playing a car racing video game that gives you a "booster". These boosters let you accelerate from your current speed to a larger speed by applying an extra constant acceleration of 5 m/s^2 for a specified time interval of 3 seconds. Normally, your car is able to accelerate at 3 m/s^2 up to a top speed of 70 m/s (about 157 mph). So – in this game – there are two choices for using your booster that make sense. (Proving the best method is one of these two choices is a bit more complicated....for now, we'll just consider these two scenarios).

   Scenario 1 – you use your booster instantly. In this scenario, you get an acceleration of 8 m/s^2 (3 m/s^2 from the car + 5 m/s^2 from the booster) for the first 3 seconds. After that, the car accelerates at 3 m/s^2 up to its top speed of 70 m/s and then moves at a constant speed. The advantage in this scenario is that you get going quicker at first.

   Scenario 2 – you use your booster after you get to your top speed. In this scenario, you use your car's normal top acceleration of 3 m/s^2 until you get to 70 m/s. Then, immediately after reaching the top speed, you apply the booster to accelerate you at 5 m/s^2 for the next 3 seconds, pushing your speed for the rest of the race higher than 70 m/s. The advantage to this approach is that you get to reach (and stay at) a higher top speed, but you do spend a longer time moving slowly.

   It turns out that the optimal strategy depends on the length of the race.

   a) Calculate how long it would take to complete a 1 mile race with scenario 1.
   b) Calculate how long it would take to complete a 1 mile race with scenario 2.
   c) Calculate how long it would take to complete a 10 km race with scenario 1. (If you were very neat and careful how you did your calculations for part (a), there are intermediate results from that part of the problem you may be able to re-use here).
   d) Calculate how long it would take to complete a 10 km race with scenario 2. (If you were very neat and careful how you did your calculations for part (a), there are intermediate results from that part of the problem you may be able to re-use here).
   e) [Extra Credit]. You should find that scenario 1 is better for a shorter race, while scenario 2 is better for a longer race. Find the distance where the ideal scenario switches. *DO NOT JUST USE GUESS AND CHECK HERE!*

4. A speeder is traveling East on a seemingly deserted country road driving at a steady 75 miles per hour. A police officer, driving West on the same road, uses his radar detector to note that the relative speed between the two cars is 115 miles per hour.

   a) If the radar detector was reading accurately, how fast were the police officer and the speeder each driving? (in meters per second).

   b) Let's say that the radar detector was used when the two vehicles were 0.8 miles apart. Both vehicles continued driving for another 20 seconds at their original speeds. After that time, the police car starts to decelerate at 2.0 m/s^2 to slow down enough to turn around and chase the speeder. (The speeder is completely oblivious and continues driving East at 75 miles per hour through this whole process). Once the officer stops, it takes 3.0 seconds for the car to turn around, and then the officer starts to travel East and accelerates from rest at a constant 1.0 m/s^2. If we define the position that the speeder was at when the speed was first detected by the officer as $x = 0$ and define East as the positive x direction:

      i) What is the x position of the police car when it stopped to turn around? (Leave your answer in meters).

      ii) What is the x position of the speeder when the police car finishes turning around and is ready to start accelerating again?

      iii) How much time elapses between when the police officer restarts from rest to when the officer catches the speeder?

      iv) What what is the x position that the two vehicles are at when the officer catches the speeder? (Leave your answer in meters).

   c) Let's say that there's a policy in place that an officer is only allowed to ticket a speeder if, at all times in the process, the officer stays within a distance D of the speeder. (As far as I know, no such policy exists.) How large could D be and have the officer allowed to give the speeder a ticket? (Another way of phrasing the question – what is the largest distance between the officer and the speeder at any time in this chase? Only consider times after the officer turned around.)