**Homework 3 Solutions**

**Problem 1.** Suppose you’re biking down the street with speed 10m/s. An ambulance is approaching you from behind at a speed of 30m/s blaring its siren at a frequency of 400Hz. You can take vsound = 343m/s.

(a) What frequency do you hear as it’s approaching?

Well,



(b) What frequency do you hear when it passes you?

And,



**Problem 2.** The ambulance is back. You’re doing 10m/s down the road again, and it’s doing 30m/s. This time it’s in front of you, coming towards you. When the ambulance passes you, your hear a frequency drop of 150Hz. What is the source frequency of the ambulance’s siren? Again, presume vsound = 343m/s.

Well on the way towards you we have:



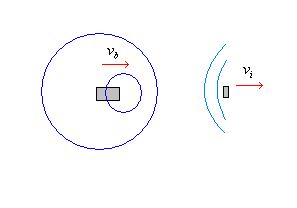
and the frequency you’d hear as its receding away from you is:



Subtracting the two we get:



**Problem 3.**  Suppose you’re a bat locating an insect. You’re traveling to the right at a speed of 7m/s. You send out an ultrasonic ping of frequency 5000Hz. It comes back 0.06s later, at a frequency of 4890Hz. (a) How far away from you is the insect?



First, since the sound wave reflects back in 0.6s, the insect is a distance



away.

(b) What is its velocity? We’ll assume for the sake of discussion that the insect and you flying along a straight line?

The speed of the insect can be calculated as follows. First the frequency of the wave intercepted by the insect will be:



These waves will be reflected back to the bat. But now, fi will act as the source frequency and the 4890Hz will be the observed frequency. So we have,



Combining these equations we have,



So the insect is flying to the right (b/c vi is positive) with a speed of 10.8m/s.

**Problem 4.** In all of our problems so far, we’ve assumed that the source and observer

are moving along the same line. But now let’s consider a different scenario, which is still broadly amenable to same analysis we did in class (that of using kinematics). Suppose you’re standing on the street y-axis at coordinate (+y). And a car is driving along the x-axis with a speed (+vs). When it gets to coordinate (+x), it honks at a slow driver (probably on Broad street in my experience) with frequency fs. Letting this instant be t = 0….

(a) Write a symbolic expression in terms of x, y, v for when this wavefront reaches you.

This would be:



(b) Write a symbolic expression in terms of x, y, v, vs, and Ts for when the second wavefront reaches you.

This would be:



(c) Write down a symbolic expression for the observed period in terms of all these variables. Don’t try to simplify it.

So To = t2 – t1. So,



(d) Using Taylor series we can make the following approximation, valid for when λ is small. Using this approximation, simplify your expression for To and get an expression for fo,



So then,



Taking the reciprocal, we get:



(e) Evaluate it for y = 50m, x = 50m, car speed 20m/s, and sound speed 343m/s, and car horn frequency 600Hz.

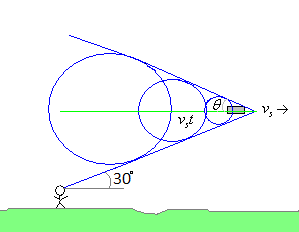
If I must,



**Problem 5.** A fighter jet is passing by directly overhead. You hear it 10s later, when it makes an angle of 30 degrees w/r to the horizon. Assuming vsound = 343m/s….

(a) What is its speed?

So it looks like this:



And we know that sinθ = v/vs. So sin(30) = v/vs → vs = v/sin(30) = 2v = 686m/s.

(b) What is its altitude?

We could do this in multiple ways. One is to simply recognize that it took 3s for the sound wave emanated directly overhead to reach your ears. Therefore h = vsound(10s) = 3430m.

\*update: Well, actually it depends on what ‘hear’ means. The analysis done here gives the correct answer if you take it to be the when you first hear it. But if you mean ‘hear’ to mean when the sonic boom passes you, then it would be analyzed as follows:

