Notes for Lecture 10

Sound, Light

In this lecture, we discussed various aspect of sound (beats, interference, decibel, Doppler effect) and then we moved on to light and discussed the plane mirror, and the law of reflection for light. What we covered in class can be found in the textbook, mostly, so I will not repeat them here. Instead, just some comments are presented.

Relativity?

Consider two situations: (1) a source of sound moving with speed v_r towards a stationary observer, and (2) an observer of sound moving with the same speed v_r towards a stationary source.

In case (1), the observed frequency is $f_o = f\frac{v}{v-v_r}$, while in case (2), the observed frequency is $f_o = f\frac{v+v_r}{v}$. Here, v is the normal speed of sound. While these two expressions are practically the same if $v_r/v \ll 1$, they do differ if v_r/v is not small. The question is "why this behavior?".

According to the relativity principle, there is no such thing as an absolute velocity, and so only relative velocities are meaningful. If you think in this way, you might led to believe that the two cases (1) and (2) *must* be equivalent to each other, since the relative velocity of the source to the observer is the same! But, wait, there is a problem. Not only do the source and the observer exist, but also there is air. In case (1), the air is (assumed to be) stationary. While in case (2), *in the observer's reference frame*, the air is moving! Since f_o is the frequency perceived by the observer, this difference is significant, and makes the two cases different.

Now, if $v_r/v \ll 1$, then the difference of the two cases due to the condition of air can be ignored, which is the reason why the two Doppler effects give practically the same result (cf. reading quiz). This is no longer true if v_r/v is not small.

However, in the case of light in free space, there *is no medium* other than vacuum. So, our reasoning above shows that the relativity principle must hold! Indeed, the Doppler effect of light in vacuum depends only on the relative velocity of the source and the observer: the above cases (1) and (2) would be completely equivalent for light propagating in vacuum.

Example T16-12

We discussed this example. One thing to note is that in this example the two loud speakers are assumed to give out sounds that are precisely the same: the phase constants ϕ for the two waves are exactly the same. This is the tacit assumption of this example, due to, e.g., the two speakers hooked up to the same sound source. Such sources of waves, like these two loud speakers, are called **coherence sources**.

Example T16-15

In this example, the Doppler shift for the echo of a sound that bounces off a moving target is measured by the very person, who sent out the original sound. Please follow the solution given during the lecture, or in the book. Note that this problem involves two legs of motion: the first leg from the time that the sound goes off and arrives at the surface of the moving object, and the second leg from the time that the reflected sound goes off from the surface to the original person. In the first leg of the motion of the sound wave, this person is the sound source, while in the second leg of the motion of the sound wave, this person is the observer. In the first leg of the motion, the surface, at which the sound wave is reflected is the observer, while in the second leg of the motion, the surface is the sound source.

This example reminds me of a speed gun that a high way patrol uses to catch speeding cars! Indeed, the Doppler effect is what such a speed gun is based on; however, it is the Doppler effect of light (radio wave), not sound. **The Doppler effect of light is given by a completely different formula!**

Law of reflection

As we start Chapter T32 and first consider a plane mirror, we use the law of reflection $\theta_i = \theta_f$.

You are quite encouraged to prove this law of reflection using Fermat's principle, as discussed on line as an extra credit question.