Physics 123 section 2 CID ____________

Homework 18

Score ________ / 30

1. (3 pts) The array of speakers in the public address system at the BYU football stadium produces waves which, near to the speakers, approximate plane waves. Imagine that the gain is turned up too high, and the PA system begins to whine, emitting sine waves with a frequency f and an intensity of I traveling at the speed of sound v. The pressure variations in the wave are given by $\Delta P = \Delta P_{max} \sin(kx - \omega t)$. What are ΔP_{max}, k, and ω in terms of ρ, f, I, and v?

2. (6 pts) Two metal-heads place their radios, tuned to different stations, next to each other to see which is the loudest. A sound detector is placed 10 meters away from the radios. It reads 95 dB when the first radio is on, and 93 dB when the second one is on. (a) What is the sound intensity, in Watts per square meter, at the detector when only the first radio is turned on? (b) What is the sound intensity at the detector when only the second radio is on? (c) What will the meter read (in dB) when both radios are on? (d) What will it read (in dB) when both radios are on if we move the meter to a distance of 25 meters away from the radios? Assume that the combined size of the two radios is much smaller than 10 meters.

3. (3 pts) A drop of water falls into a perfectly calm pond generating ripples that travel out in circular rings. Prove that as each ring expands, the amplitude of the ring drops off as $1/\sqrt{r}$ where r is the radius of the ring. Assume that the waves propagate non-dispersively (i.e., the radial thickness of a ring doesn't change as the ring expands).

4. (3 pts) A firework explodes 77.2 meters above you. You record the explosion with a microphone and you find that the average intensity of the sound was 71.3 dB and that the sound lasted for 2.32 ms. How much was the total sound energy released by the explosion (in Joules)? Assume that the sound waves were spherical.

5. (5 pts) Imagine that I am standing 20 meters from an object which is emitting sound. A meter I am holding indicates that the sound level is 75.3 dB. Now I move toward the object until I am just 15 meters away. (a) What will my meter read now (in dB) if the object is a very small speaker which is emitting nearly perfectly spherical waves? (b) What will my meter read now if the object is a huge array of speakers emitting a nearly perfect plane wave?

6. (7 pts) A friend of mine gets into his car and honks the horn. I measure its frequency to be 421 Hz. Then he drives away, turns around, and drives toward me. He honks the horn again, and now I measure a frequency of 428.2 Hz. (a) How fast is my friend going? (b) What frequency will I hear right as he is passing me? (c) What frequency will I hear after he has passed me and is driving away? Assume that the speed of sound is 343 m/s.

7. (3 pts) You are in the passenger seat of a car which is moving at 20.2 m/s on a road which runs right along a train track. You have your window open and your arm is out the window doing the "airplane wing" thing with your hand. A train approaches you from behind travelling at 47.3 m/s blowing its horn. You hear the trains horn at a frequency of 648 Hz. What frequency will you hear after the train has passed you? Assume that the speed of sound is 343 m/s.

Extra problems I recommend you work (not to be turned in)

- Why is it important that the two radios in problem 2 be tuned to different stations?
- In the first problem you explored how the amplitude of 2-dimensional "spherical waves" waves drop of. Now imagine that you are on a starship and the transporter malfunctions, sending you to a parallel universe. Everything seems strange. You notice that if you double your distance from a tiny object which is emitting sound, the sound intensity goes down by a factor of 16. How many spatial dimensions are there in this universe?
- If a 100 Watt audio amplifier plugged into a speaker could really put out 100 Watts of audio power (they don't), what would be the intensity (in dB) of sound 1 meter from a small speaker driven by a 100 Watt amplifier running at its maximum amplitude?

- In my lab we have a device called an acousto-optic modulator. If you send light through it in just the right way, you get a beam out which is just like the beam coming in except the phase changes linearly in time. Imagine I send light in who's electric field is described by a sine wave: $E = E_0 \sin(kx - \omega t)$. After passing through the modulator, the field is shifted in phase: $E = E_0 \sin(kx - \omega t + \phi)$. The phase ϕ is not a constant, but changes linearly in time as $\phi = At$. Show that the wave exiting the modulator is equivalent to a sine wave without a ϕ term but which has a higher frequency $\omega' = \omega + A$.