Physics 221
Quiz #3

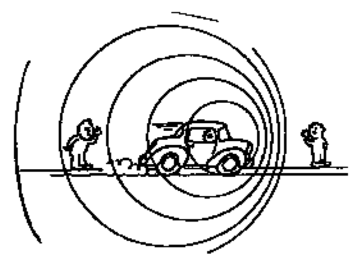
Names: ________________Solution________________

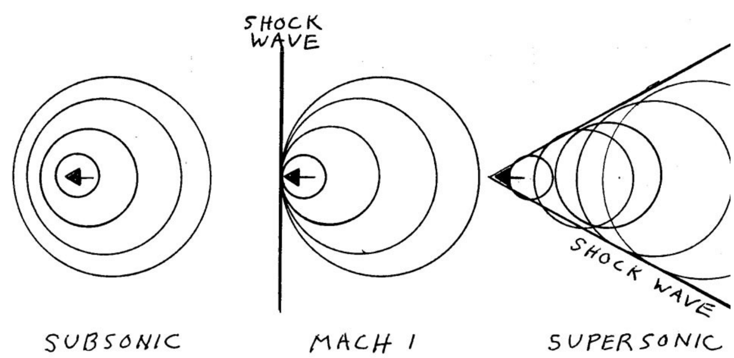
1. Compare and Contrast the Doppler Effect and a Sonic Boom.
   a. Do the actual sounds heard have something in common? Specifically explain what we perceive in each case and how these are different or similar.

These are two distinct sounding phenomena. The Doppler Effect is when you hear a higher frequency as an object is approaching and a lower frequency as it is receding compared to the frequency being emitted by the source. With a Sonic boom, you hear and very loud sound all at once (boom for a jet or a crack from a whip) as the disturbance in the air passes by you which is caused by an object traveling faster than the speed of sound.

   b. How about the underlying physics, how closely related are they (use diagrams to support your answer)? First describe how each works and then show how the physics is similar or different.

The physics of each is actually quite similar. With the Doppler effect since there source is approaching an observer, each crest of the wave is emitted closer to the observer than the last. This causes the received wavelength to be shorter and the receiver then hears a higher pitched sound. Vice versa if the source is moving away. A sonic boom happens because the source is moving faster than the sound waves so each crest of the wave is emitted beyond the distance the previous crest of the wave has managed to travel. A cone is created trailing the object where the wave fronts overlap. This overlap creates a huge disturbance in the air and that disturbance is the sonic boom.





2. A particular speaker at a concert puts out 20 Watts of power.
   a. Calculate both the intensity and the intensity level at 3 meters.

Intensity: $I = \frac{P}{4\pi r^2} = \frac{20\ W}{4\pi(3m)^2} = 0.177\ \text{W/m}^2$,

Intensity Level is decibels $\beta = 10 \log\left(\frac{I}{I_o}\right) = 10 \log\left(\frac{0.177\ W/m^2}{1 \times 10^{-12} W/m^2}\right) = \mathbf{112\ dB}$

b. If there were two identical speakers next to each other, by how much would the intensity level increase?

Intensity is doubled since the power is double. So I will be 0.354 W/m²

Use this with the Intensity Level equation to find new dB

$\beta = 10 \log\left(\frac{I}{I_o}\right) = 10 \log\left(\frac{0.354\,W/m^2}{1\,x\,10^{-12} W/m^2}\right)$ = **115 dB**

This is an example of the 3dB rule. If you double the intensity, the decibels increase by 3.

c. Determine how far you must stand from the single speaker to receive an intensity level equal to 90 dB which is safe for approximately 2 hours exposure?

90 dB = $10 \log\left(\frac{I}{1\,x\,10^{-12} W/m^2}\right)$ solve for I by dividing by 10 and then placing both sides as exponents of 10. $10^{\log(x)} = x$.

$9 = \log \frac{I}{1\,x\,10^{-12} W/m^2}$ now $10^9 = \frac{I}{1\,x\,10^{-12} W/m^2}$ so $I = 1 \times 10^{-3}$ W/m²

Now use your new Intensity to find r the distance.

$I = \frac{P}{4\pi r^2} = 1 \times 10^{-3}\ W/m^2 = \frac{20\ W}{4\pi (r)^2}$ r = **39.9 m**

3. On a very cold day, -10°C, Walter is driving down the road at 15 m/s and sees a car that is honking its horn. Walter has perfect pitch along with training to help him recognize exact frequencies. He identifies the frequency of the sound he's hearing at exactly 457 Hz. It's a blizzard so he is having a hard time telling if the car is moving, much less if it's moving towards or away from him. Since he also happens to know that this particular make of car puts out a frequency of 425 Hz from its horn, since we know Walter is great with numbers he calculates in his head the car's exact speed to distract himself from the tense driving conditions.
   a. What is its speed?
   b. Is the car moving towards or away from Walter?

$f' = f\frac{v \pm v_o}{v \pm v_s}$, f' = 457 Hz, f = 425 Hz, v_o = 15 m/s, v_s = ?, v = speed of sound in air at -10°

$v = 331\ m/s \sqrt{1 + \frac{-10}{273}} = 324.9\ m/s$ 457 Hz = 425 Hz $\frac{324.9+15}{324.9 - v_s}$

$1.075\,(324.9 - v_s) = 339.9$

v_s = **8.8 m/s**

You hear a higher frequency than the source puts out so the two cars are getting closer. Because the frequency change is fairly large, it is likely that the car is approaching Walter but you should do the math to be sure.

When I did the math I chose to put in – for the v_s assuming it was moving towards Walter's car. If this assumption is correct, my speed comes out positive. If it is incorrect, the speed will come out negative. If you use the correct signs with the Doppler shift equation, the value of v should be positive (it's the magnitude).

$f' = f\frac{v \pm v_o}{v \pm v_s}$, + observer moving towards, - observer moving away, - source moving towards, + source moving away.

$v = 331\ m/s \sqrt{1 + \frac{T}{273}}$ T in degrees C $I = \frac{P}{4\pi r^2}$ $\beta = 10 \log\left(\frac{I}{I_o}\right)$ $I_o = 1 \times 10^{-12}$ W/m²