PROBLEM SET 3
SOUND

Part A

1. D
2. E
3. D
4. B
5. A
6. C
7. E
8. A
9. D
10. B

Part B

1. a) The intensity is proportional the power of the source and inversely proportional to the distance square:

$$I = \frac{P}{4\pi r^2} = \frac{2\times10^{-3}}{4\pi(8)^2} = 2.48\times10^{-6} W/m^2 \mathrm{I}$$

b) The intensity (I) and the intensity level (β) are two distinct variables.

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{2.48\times10^{-6}}{1\times10^{-12}}\right) = 63.95dB \approx 64dB$$

c) we cannot simply add *log*, therefore, we have to find the intensity of the 4 dogs at 8m and then find the intensity level.

$$I_{tot} = 4I = 4\times(2.48\times10^{-6}) = 9.92\times10^{-6} W/m^2$$

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{9.92\times10^{-6}}{1\times10^{-12}}\right) = 69.97dB \approx 70dB$$

2. a) We can find the intensity level from the intensity:

$$I = \frac{P}{4\pi r^2} = \frac{20}{4\pi(3)^2} = 0.176 W/m^2$$

$$\beta = 10\log\left(\frac{I}{I_o}\right) = 10\log\left(\frac{0.176}{1\times10^{-12}}\right) = 112dB$$

b) from the sound intensity equation, we can isolate to find the intensity

$$\beta = 10\log\left(\frac{I}{I_o}\right) \Rightarrow I = I_o \times 10^{\left(\frac{\beta}{10}\right)}$$

$$I = 10^{-12} \times 10^{\left(\frac{50}{10}\right)} = 1\times10^{-7} W/m^2$$

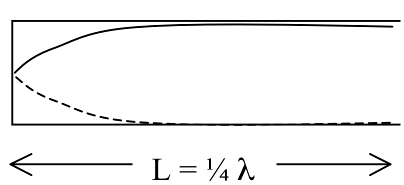
The power didn't change because the source is the same, therefore, we can find the distance at which the source is located:

$$I = \frac{P}{4\pi r^2} \Rightarrow r = \sqrt{\frac{P}{4\pi I}} = \sqrt{\frac{20}{4\pi(10^{-7})}} = 3.98\times10^3 m$$

c) Given that the intensity is $I = 0.176W/m^2$ and the distance is $r = 3.98\times10^3 m$, we can find the power needed from the source

$$I = \frac{P}{4\pi r^2} \Rightarrow P = 4\pi r^2 I = 4\pi(3.98\times10^3)^2(0.176) = 3.50\times10^7 W$$

3. a) The minimum length of pipe will corresponds to the length of the fundamental frequency

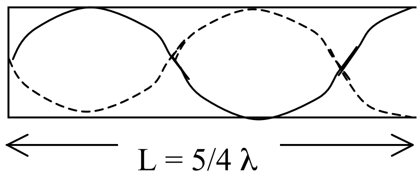


assume that v_{sound} = 340 m/s

$$v = f\lambda \Rightarrow \lambda = \frac{v}{f} = \frac{340}{300} = 1.13m$$

$$L = \frac{1}{4}\lambda = \frac{1}{4}(1.13) = 0.283m$$

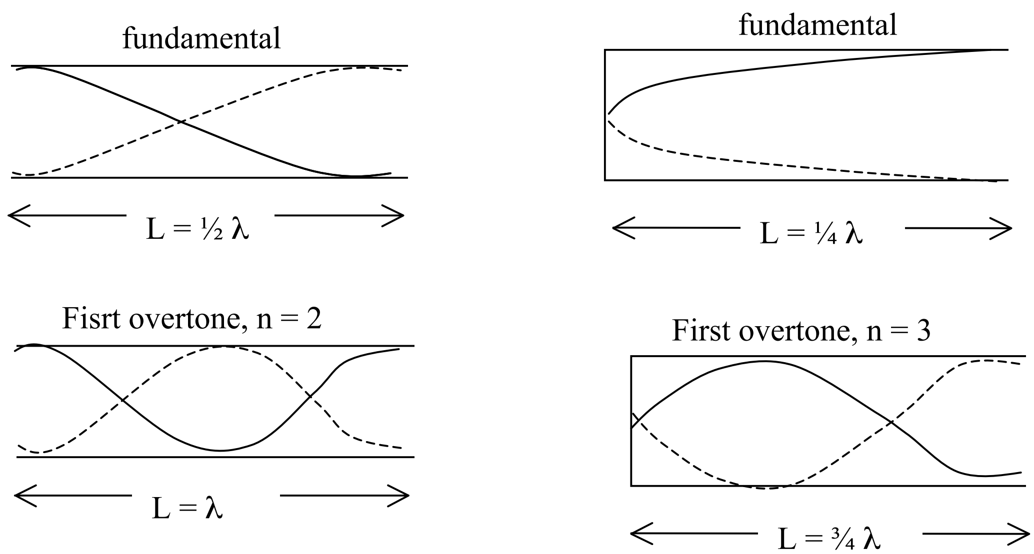
b) For the fifth harmonic



$$v = f\lambda \Rightarrow \lambda = 1.13m$$

$$L = \frac{5}{4}\lambda = \frac{5}{4}(1.13) = 1.41m$$

4.



Given that v = 340 m/s

$$v = f\lambda \Rightarrow \lambda = \frac{v}{f} = \frac{340}{300} = 1.13m$$

$$L_{open} = \frac{\lambda}{2} = \frac{1.13}{2} = 0.567m$$

and the frequencies are equal for the first overtone of the closed and open pipe.

$$f_{closed} = f_{open} = 600\,Hz$$

$$\frac{3v}{4L_{closed}} = \frac{2v}{2L_{open}}$$

$$L_{closed} = \frac{3\left(L_{open}\right)}{4} = \frac{3(0.567)}{4} = 0.425m$$

[Make sure that you understand the signification of *overtone* and *harmonic*, the possible wavelengths and frequencies associated with the open and closed pipe.]

5.a) We know that

$$v = f\lambda = \sqrt{\frac{F_t}{\mu}} \Rightarrow f = \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{F_T}{\mu}}$$

If the frequency goes up tension will increase and if the frequency goes down, tension will decrease.

b) number of beats = 4 ($f_{beat} = |f_1 - f_2|$) and frequency = 294Hz

The new frequency = 294 ± 4

$$294 = \frac{1}{\lambda}\sqrt{\frac{F_1}{\mu}} \qquad\qquad 298 = \frac{1}{\lambda}\sqrt{\frac{F_2}{\mu}}$$

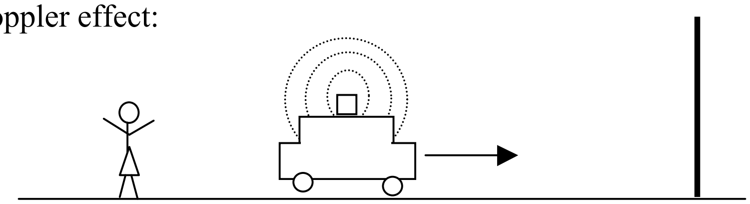
$$\text{or } \frac{298}{294} = \left(\frac{F_2}{F_1}\right)^{1/2} \qquad \text{or} \qquad \frac{F_2}{F_1} = \left(\frac{298}{294}\right)^2 \to F_2 = 1.027F_1$$

Increase in frequency will increase the tension. And if the frequency decreases, the tension decreases also. Try it!

b) The fractional increase (or decrease) $\frac{F_2 - F_1}{F_1} = \frac{1.027F_1 - F_1}{F_1} = 0.027 = 2.7\%$.

If the frequency goes up, the tension will go up by 2.7%. If the frequency goes down, the tension will decrease by 2.7%. Try it!

6. Using Doppler effect:



a) the listener is at rest and the siren moves away from the listener:

$$f_{listener} = f_{siren}\left(\frac{v}{v+v_{siren}}\right) = 1000\left(\frac{340}{340+10}\right) = 971.4Hz$$

b) the cliff is at rest and the siren moves toward the cliff

$$f_{cliff} = f_{siren}\left(\frac{v}{v-v_{siren}}\right) = 1000\left(\frac{340}{340-10}\right) = 1030.3Hz$$

both listener and the cliff are the rest

$$f_{listener} = f_{cliff}\left(\frac{v}{v}\right) = f_{cliff} = 1030.3Hz$$

c) the beat frequency: $f_{beat} = | f_2 - f_1 | = | 1030.3 - 971.4 | = 58.9Hz$

d) repeat the same procedure as in parts a, b and c but now the listener is moving toward the siren at 5m/s.

$$f_{listener} = f_{siren}\left(\frac{v+v_{listener}}{v+v_{siren}}\right) = 1000\left(\frac{340+5}{340+10}\right) = 985.7Hz$$

$$f_{cliff} = f_{siren}\left(\frac{v}{v-v_{siren}}\right) = 1000\left(\frac{340}{340-10}\right) = 1030.3Hz$$

$$f_{listener} = f_{cliff}\left(\frac{v+v_{listener}}{v}\right) = 1030.3\left(\frac{340+5}{340}\right) = 1045.5Hz$$

$$f_{beat} = \left|f_2 - f_1\right| = \left|985.7 - 1045\right|.5 = 59.7Hz$$

7. Using Doppler effect:

a) Both subs are moving toward each other

$$f_{sub2} = f_{sub1}\left(\frac{v+v_{sub2}}{v-v_{sub1}}\right) = 2000\left(\frac{1540+29}{1540-6}\right) = 2045Hz$$

b) the frequency reflected by the second sub is equal to the frequency received by the second sub

$$f_{received,sub2} = f_{reflected,sub2} = 2045Hz$$

$$f_{sub1} = f_{sub2}\left(\frac{v + v_{sub1}}{v - v_{sub2}}\right) = 2045\left(\frac{1540 + 6}{1540 - 29}\right) = 2092Hz$$