Notre Dame University
Faculty of Natural and Applied Sciences
Department of Sciences
Spring 2009-2010

May 11, 2010

PHS 203
Exam II

NAME: ________________________________ **ID:** ________________

SECTION: ___

Only calculators are allowed

Not allowed: mobile phones, any written material, borrowing calculators or pens during the exam.

Write in detail the solutions of the exercises in Part I. Failing to do so will deny you any credit, even if the selected solution happens to be correct. Write in detail the solutions of the problems in Part II.

GRADING

Part I: 10×6 = 60 marks
Part II Problem 1 : 20 marks
Part II Problem 2: 20 marks
Total : 100 marks

PART I:

1. A point source emits sound waves with an average power output of 80.0 W. The intensity 3.00 m from the source is:
   - **a.** 0.707 W/m^2
   - **b.** 2.122 W/m^2
   - **c.** 56.29 mW/m^2
   - **d.** 1.415 W/m^2
   - **e.** None of the above, my answer is _____________

Solution: $I = \frac{\mathcal{P}}{4\pi r^2} = \frac{80}{4\pi 3^2} = 0.707 \text{ W/m}^2$

2. As an ambulance travels east down a highway at a speed of 33.5 m/s, its siren emits sound at a frequency of 400 Hz. A person is in a car traveling west at 24.6 m/s on the same highway. As the car approaches the ambulance, the frequency heard by the person is:
   - **a.** 475 Hz
   - **b.** 338 Hz
   - **c.** 409 Hz
   - **d.** 389 Hz
   - **e.** None of the above, my answer is _____________

Solution: $f' = f\frac{v+v_D}{v-v_S} = \frac{343+33.5}{343-24.6} = 475 \text{ Hz}$

3. Suppose that you hear a clap of thunder 16.2 s after seeing the associated lightning stroke. The speed of sound waves in air is 343 m/s, and the speed of light in air is 3×10^8 m/s. In this case, the distance separating you from the lightning source is:
   - **a.** 5556.6 m
   - **b.** 48.6×10^8 m
   - **c.** 48.6×10^8 km
   - **d.** 58 km
   - **e.** None of the above, my answer is_____________

Solution: $16.2 = t_{thunder} - t_{lightning} = \frac{d}{343} - \frac{d}{3\times10^8} \Rightarrow d = 16.2\left(\frac{1}{343} - \frac{1}{3\times10^8}\right)^{-1} = 5556.6 \text{ m}$

4. A bat can detect very small objects, such as an insect whose length is approximately equal to one wavelength of the sound the bat makes. If bats emit a chirp at a frequency of 60.0 kHz, and if the speed of sound in air is 340 m/s, then the smallest insect a bat can detect has a length of:

a. 5.717 mm
b. 174.9 mm^3
c. 0.175 cm
d. 0.572 cm^3
e. None of the above, my answer is _____________

Solution: $\lambda = \frac{v}{f} = \frac{343}{60\times10^3} = 5.667\text{mm}$

5. As a sound wave travels through the air, it produces pressure variations (above and below atmospheric pressure) that are given by $\Delta P = 1.27\ \sin(\pi.x - 340\pi t)$ in SI units. The amplitude of this sound wave in air ($\rho_{\text{air}} = 1.20\ \text{kg/m}^3$) is:
   a. 2.9 μm
   b. 9.1 μm
   c. 1.27 μm
   d. 2 m
   e. None of the above, my answer is _____________

Solution: $s_m = \frac{\Delta P_m}{\rho\omega v} = \frac{\Delta P_m}{\rho\omega\left(\omega/k\right)} = \frac{1.27}{1.2\times(340)^2\times\pi} = 2.9\ \mu\text{m}$.

6. A vacuum cleaner has a measured sound level of 70 dB. The intensity of this sound is:
   a. 10^{-5} W/mm^2
   b. 7×10^{-5} W/m^2
   c. 10^{-5} W/cm^2
   d. 7×10^{-5} W/cm^2
   e. None of the above, my answer is _____________

Solution: $70 = 10\log\frac{I}{I_0} \Rightarrow I = I_0 10^7 = 10^{-5}\ \text{W/m}^2$

7. The length of a pipe closed at one end with a third lowest frequency 721 Hz is:
   a. 35.7 cm
   b. 71.4 cm
   c. 59.5 cm
   d. 47.6 cm
   e. None of the above, my answer is _____________

Solution: $f = \frac{5v}{4L} \Rightarrow L = \frac{5v}{4f} = \frac{5\times343}{4\times721} = 59.5\ \text{m}$.

8. While attempting to tune the note C at 523 Hz, a piano tuner hears 2 beats/s between a reference oscillator and the string. The possible frequencies of the string, considered slightly untighten, is:

a. 521 Hz
b. 525 Hz
c. 521 beats/min
d. 525 beats/s
e. None of the above, my answer is_____________

Solution: $f = f_1 - f_2 \Rightarrow f_2 = f - f_1 = 523 - 2 = 521 \text{ Hz}$.

9. When a metal pipe is cut into two pieces, the lowest resonance frequency in one piece is 256 Hz and that for the other is 440 Hz. The lowest resonant frequency that would have been produced by the original length of pipe is:

a. 162 Hz
b. 163 Hz
c. 160 Hz
d. 161 Hz
e. None of the above, my answer is _____________

Solution: $f = \frac{v}{2L} = \frac{v}{2(L_1 + L_2)} = \frac{v}{2\left(\frac{v}{2f_1} + \frac{v}{2f_2}\right)} = \frac{f_1 f_2}{f_1 + f_2} = 162 \text{ Hz}$.

10. The tip of a circus ringmaster's whip travels at Mach 1.38 (that is $v_S/v = 1.38$). The angle between the shock front and the direction of the whip's motion is:

a. 46.44°
b. 23.22°
c. 92.88°
d. 90°
e. None of the above, my answer is _____________

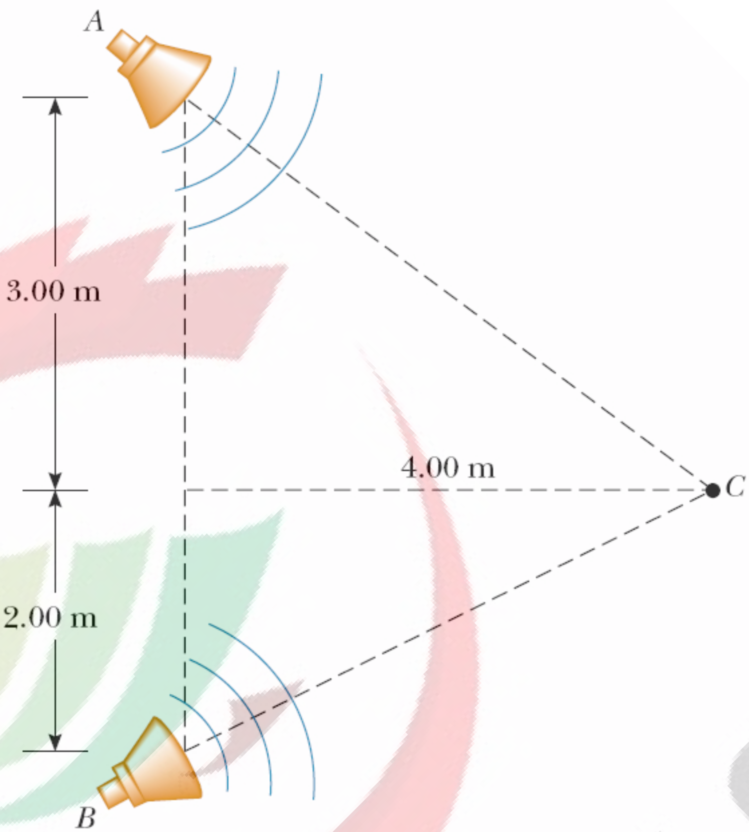
Solution: $\theta = \sin^{-1}\frac{v}{v_S} = \sin^{-1}\frac{1}{1.38} = 46.44°$.

PART II

Problem 1

Two small speakers emit spherical sound waves of different frequencies. Speaker *A* has an output of 1.00 mW, and speaker *B* has an output of 1.50 mW. Determine the sound level (in decibels) at point *C* (see the Figure below) if

a. only speaker *A* emits sound,
b. only speaker *B* emits sound,
c. both speakers emit sound.



Solution:

a. $\beta = 10\log\frac{I_c}{I_0}$

If only speaker A emits sound, the intensity at C is $I_C = \frac{P_A}{4\pi(AC)^2} = \frac{10^{-3}}{4\pi(3^2+4^2)} = \frac{10^{-5}}{\pi}$ W/m^2; hence the sound level is $\beta = 10\log\frac{10^7}{\pi} = 65.03$ dB.

b. $\beta = 10\log\frac{15\times10^7}{8\pi} = 67.76$ dB.

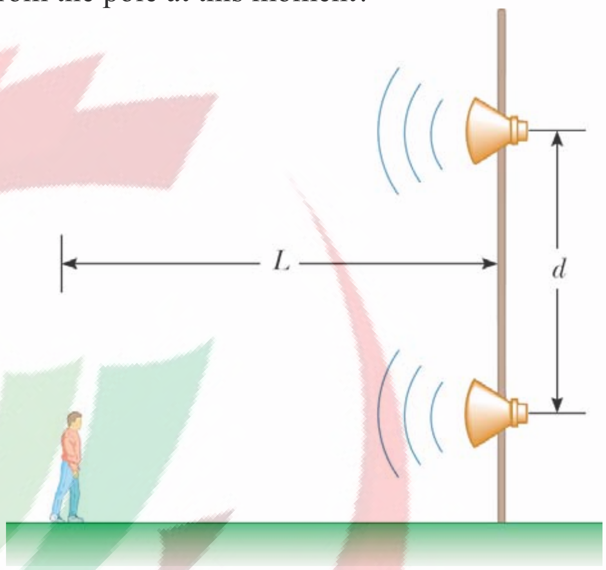
c. If both speakers emits sound then the intensity at C is $I_C = \frac{10^{-5}}{\pi} + \frac{15\times10^{-5}}{8\pi} = \frac{23\times10^{-5}}{8\pi}$ W/m^2; hence the sound level at C is $\beta = 10\log\frac{23\times10^7}{8\pi} = 69.61$ dB.

Problem 2

Two speakers are driven by the same oscillator with frequency of 200 Hz. They are located 4.00 m apart on a vertical pole. A man walks straight toward the lower speaker in a direction perpendicular to the pole, as shown in the Figure below. Consider the speed of sound to be 330 m/s and L = 3 m, and ignore any sound reflections coming off the ground.

a. What is the second lowest frequency $f_{\min,2}$ that gives minimum signal at the listener's location?

b. How far is he from the pole at this moment?



Solution:

a. $f_{\min,2} = \frac{v}{\lambda} = \frac{330}{\lambda}$

Minimum signal means destructive interference; hence $\lambda = \frac{2\pi\Delta l}{\phi}$. Here Δl is the path length difference between the two speakers which is equal to $\sqrt{L^2+d^2}-L$ and ϕ is their phase difference equal to $(2n+1)\pi$.

Thus, we thus obtain $\lambda = \frac{2\pi\sqrt{L^2-d^2}-L}{(2n+1)\pi} = \frac{2\sqrt{L^2-d^2}-L}{(2n+1)}$, and

$$f_{\min,2} = \frac{330(2n+1)}{2\left(\sqrt{L^2-d^2}-L\right)} = \frac{330(2+1)}{2\left(\sqrt{L^2-d^2}-L\right)} = 247.5\,\text{Hz}.$$

b. The man is 3 m far from the pole at this moment.