Chapter 9
Sound
9.1 Speed and Intensity of Sound — Homework # 71

I

01. A hiker, who is also an avid physics student, encounters a lake with a high cliff at the far border of the lake on a 20.0°C day. The student estimates the breadth of the lake by emitting a short shout and timing when the echo from the cliff is heard. If it takes 2.85 s for the echo to return, what is the breadth of the lake?

02. What is the sound level of a sound wave whose intensity is 1.0×10^{-7} W/m^2?

03. What is the intensity of a sound whose sound level is 40 dB?

II

04. Studies indicate that humans can distinguish a difference of sound levels of two sounds as small as about 1.0 dB.
    a.) What is the ratio of the intensities of these two sounds?
    b.) What is the ratio of the amplitudes of these two sounds?

05. A stereo tape recorder is rated to have a signal-to-noise ratio of 67 dB (in other words the signal, or music that is played, is 67 dB louder than the noise, or hissing, that the recorder inherently plays). What is the ratio of the intensities of the signal and the background noise?

06. If two firecrackers produce an sound level of 95 dB at a certain distance away, what will be the sound level at this location if only one firecracker were exploded at the same source location?

07. An 82-dB sound wave strikes an eardrum whose area is 4.5×10^{-5} m^2.
    a.) How much energy is absorbed by the eardrum per second?
    b.) How much total energy is absorbed by the eardrum if the sound lasts 3.0 s?

III

08. A man jumps off a burning ship on a 25.0°C day and swims away. When the man is quite a distance away, he swims underwater to get past some small debris. While underwater he hears an explosion from the ship. He re-emerges to the surface and hears a second explosion 1.850 s after the first explosion. If the ship, indeed, only experienced one explosion, how far from the ship was the man when the ship exploded? (See Homework #68 in "Chapter 8-Simple Harmonic Motion and Waves" for the table of "Selected Physical Properties of Various Materials")

09. A person drops a stone from the top of a 10-story tall building onto the pavement below on a 20.0°C day. If the person hears the sound of the stone striking the pavement 3.34 s later, how tall is the building?

ANSWERS: **01.** 489 m **02.** 50 dB **03.** 1.0×10^{-8} W/m^2 **04.** a.) 1.26 b.) 1.12 **05.** 5.01×10^6
06. 92 dB **07.** a.) 7.13×10^{-9} J/s b.) 2.14×10^{-8} J **08.** 847 m **9.** 50.0 m

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9.2 Sources of Sound: Vibrating Strings and Air Columns Homework # 72

I

01. The G string on a violin has a fundamental frequency of 196 Hz. The length of the vibrating portion is 32.0 cm. Where must this G string be fingered such that it will vibrate with a fundamental frequency of 261 Hz?

02. A guitar string is 65.0 cm long and has a mass of 4.60 g and is tuned to play low B (247 Hz).
    a.) Under what tension must the string be placed to achieve the desired sound (frequency)?
    b.) How far from the end of the string must the finger be placed to play E above middle C (329 Hz)?

03. An organ pipe is 70.0 cm long. On a 20.0°C day, what are the fundamental and first two overtones if the pipe is _____?
    a.) closed at one end b.) open at both ends

04. A flute is designed to play middle C (262 Hz) as the fundamental frequency when all the holes are covered at 20.0°C.
    a.) Approximately how long should the distance be from the mouthpiece to the far end of the flute?
    b.) How far from the end should the hole be that must be uncovered to play D above middle C (294 Hz)?

05. Determine the length of a closed organ pipe that emits middle C (262 Hz) when the temperature is 15.0°C?

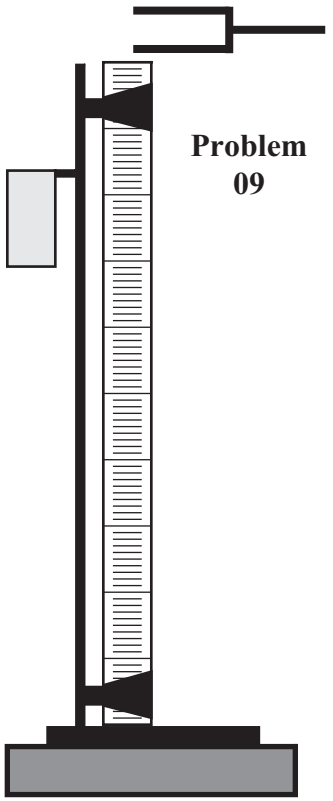
II

06. An organ is in tune at 20.0°C. By what fraction will the frequency be off at 0.0°C?

07. An open organ pipe is to have a fundamental frequency of 262 Hz at 20.0°C.
    a.) How long must the pipe be to produce this sound?
    b.) What would be the fundamental frequency if it were filled with helium? (See Homework #68 in "Chapter 8-Simple Harmonic Motion and Waves" for the table of "Selected Physical Properties of Various Materials")

08. A pipe in air at 20.0°C produces two successive harmonics at 240 Hz and 280 Hz.
    a.) Is it an open or closed tube? b.) What must be the length of this tube?

09. A long, vertical tube is filled with water to the top on a 20.0°C day. A tuning fork is held over the mouth of the tube and the water is slowly lowered by draining water out of a hole in the bottom of the tube. (The level of the water in the tube can be controlled via a clamp attached to rubber tubing connected to the hole in the bottom of the tube.) When the water is 16.7 cm below the top of the tube the volume of the sound suddenly gets significantly louder. You continue lowering the water level in the tube until the sound again gets significantly louder. See diagram to the right.
    a.) What is the water level in the tube now?
    b.) What is the frequency of the tuning fork?
    Hint: Changing the water level changes the length of the column (tube) of air above the water level. The sound wave resonates in this column of air. The water creates a barrier so this is a closed tube of air.



Problem 09

ANSWERS: **01.** 8.0 cm (24.0 cm) **02.** a.) 730 N b.) 16.2 cm (48.8 cm) **03.** a.) 122.5 Hz, 367.5 Hz, 612.5 Hz **03.** b.) 245 Hz, 490 Hz, 735 Hz **04.** a.) 0.655 m b.) 0.0712 m (0.583 m) **05.** 0.324 m **06.** 0.0350 **07.** a.) 0.655 m b.) 574 Hz **08.** a.) open b.) 4.30 m **09.** a.) 50.1 cm b.) 512 Hz

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9.3 Wave Beats — Homework # 73

I

01. Two horns emitting sounds of frequency 437 Hz and 441 Hz, respectively, produce beats of what frequency?

02. A piano tuner uses a tuning fork with a frequency of 330 Hz to tune a piano string. When he strikes the tuning fork and strikes the key of the piano that vibrates this string he notices a beat occurring every 1.50 s. How far off in frequency is the piano string?

03. Middle C (262 Hz) and C# (277 Hz) are played together.
    a.) What will be the "beat frequency"?
    b.) What will be the "beat frequency" if both of these sounds are played two octaves lower (reduced by a factor of $2^2 = 4$)?

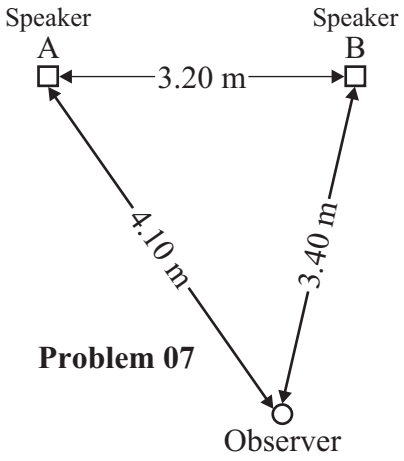
II

04. Two violin strings are tuned to the same frequency of 294 Hz. The tension in one string is increased by 7.00%. If the two strings are now played together, what will be the frequency of the beats?

05. Two piano strings, string A and String B, are supposed to be vibrating at 132 Hz, but a piano tuner hears a beat every 0.333 s when they are played simultaneously. Assume string A is correctly vibrating at 132 Hz.
    a.) What are the possible frequencies of string B?
    b.) By what percent must the tension in string B be increased (or decreased) to bring them in tune?

06. Two identical flutes each tuned to play middle C (262 hz) at 20.0 °C. One is playing in a room that is 20.0 °C while the other is playing from just inside of a walk-in freezer (with the door open) with a temperature of 0.0 °C. An observer is in the room at a location that is between the two flutes. What frequency of beats will the observer detect. Ignore any difference in the speed of sound between the flutes **AFTER** the sound waves leave each flute (but the air inside the flutes is considered to be the at the temperature of their respective environments).

07. Two loud speakers are 3.20 m apart with an observer standing 3.40 m from the one speaker and 4.10 m from the other speaker in a large open field. The loudspeakers are connected to a wave generator that can vary the frequency of the monotone sound wave produced by the speakers. Assume the waves are in phase when they leave the speakers and the temperature of the air is a constant. The diagram to the right shows a top view of this field and indicates the relative orientation of the speakers and the observer. Ignore any reflections of the sound waves off the gorund or any other object.
    a.) What is the longest wavelength at which constructive interference will occur?
    b.) What is the longest wavelength at which destructive interference will occur?



Problem 07

08. A source emits a sound of wavelengths 3.15 m and 3.50 m in air at 20.0 °C.
    a.) How many beats per second will be heard?
    b.) How far apart from one another in space are the regions of maximum intensity?

ANSWERS: **01.** 4 Hz **02.** 0.667 Hz **03.** a.) 15 Hz b.) 3.75 Hz **04.** 10.1 Hz
05. a.) 129 Hz, 135 Hz b.) 4.71% (4.40%) **06.** 9.17 Hz **07.** a.) 0.70 m b.) 1.40 m
08. a.) 10.9 Hz b.) 31.5 m

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9.4 Doppler Effect — Homework # 74

Note: Unless Otherwise stated, assume the temperature, *T*, is 20.0°C.

I

01. The predominant frequency of a certain police car's siren is 1650 Hz when at rest. What frequency would an observer detect if the car were moving at 30.0 m/s _____ the observer.
    a.) toward b.) away

02. A firehouse public alarm whistle emits a sound of 1250 Hz. What frequency would an observer detect if the observer were in a car moving at 45.0 km/h _____ the alarm.
    a.) toward b.) away

II

03. Two trains emit whistles with identical frequencies of 465 Hz. One train is at rest while the other is moving at 35.0 km/h away from an observer standing near the tracks on a 25.0°C. What beat frequency will the observer detect?

04. One of the uses of sonar is to detect the movement of the chest of a fetus. Sound waves with a frequency of 1.00×10^6 Hz are directed at the chest of a fetus. These waves travel through the body of the mother at a speed of 1500 m/s. What will be the maximum expected shift in frequency if the chest of a normal fetus moves at a maximum speed of 0.10 m/s? Hint: The sonar waves reflect off the chest of the fetus making his chest the source of the wave-it is the source of the wave that is moving, not the observer.

05. A police radar gun which operates at a frequency of 15 GHz (1 GHz-gigahertz = 1×10^9 Hz) is mounted in a police car that is traveling at 40.0 km/h down a long straight road. The radar is pointed at a car traveling at 70.0 km/h towards the police car. What will be the frequency of the beats detected by the radar system (these beats are created by the interference of the transmitted signal and the reflected wave)? Since radar is an electromagnetic wave, it travels at the speed of light (3×10^8 m/s). Hint: When the radar waves reflect off the oncoming car, that car becomes the source of the waves and the police car's radar system is the observer.

ANSWERS: **01.** a.) 1808 Hz b.) 1517 Hz **02.** a.) 1296 Hz b.) 1204 Hz **03.** 12.7 Hz **04.** 66.7 Hz **05.** 1530 Hz