**The Calculator Pad – Sound and Music**

From <http://www.physicsclassroom.com/calcpad/sound/problems.cfm>

**Problem 1:**

aa. The speed (**v**) at which sound travels through air is dependent upon the temperature of the air and seems to follow the equation **v = 331 m/s + 0.6 m/s/°C \* T** where **T** is the Celsius temperature of the air. Determine the speed of sound …

a. … on a cold day when the outdoor temperature is 4°C.

b. … inside the school where the temperature is 24°C.

c. … on a warm day when the outdoor temperature is 38°C.

**Problem 2:**

aa. Herds of African elephants are generally spread over large areas. Infrasonic sound waves (sound waves below the human range of frequency detection) are used by these elephants to locate each other and to communicate. Sound waves with low frequencies have a greater ability to bend around obstacles and generally carry further. Scientists have detected sound waves with frequencies as low as 13 Hz being produced by elephants. Assuming a speed of sound of 350 m/s, determine the wavelength of these sounds waves.

**Problem 3:**

aa. Indoor pests such as mice and other rodents are sensitive to ultrasonic sound waves (sound waves above the human range of frequency detection). Some companies have produced (allegedly) rodent repellant devices that emit ultrasonic waves with frequencies of approximately 45 kHz. Assuming a speed of sound of 344 m/s, determine the wavelength of these sounds waves.

**Problem 4:**

aa. Mama G used to be the leader of South's Pep Club. As she started in on a round of *Wash Them Down the River*, her voice would ring out at an attention-drawing 855 Hz. Assuming a speed of sound in the Titan Dome of 355 m/s, determine the wavelength of the sound waves produced by Mama G.

**Problem 5:**

aa. On a recent PE-sponsored adventure education program, students went hiking at Devil's Head State Park. At one point, Jeremy let out a holler that reflected off a nearby rocky cliff and was detected as an echo 1.80 seconds later. Determine the distance to the rocky cliffs. Assume a speed of sound of 344 m/s.

**Problem 6:**

aa. A deep sea ocean vessel uses SONAR to detect the ocean's bottom. Sound waves are emitted from the surface of the ocean and travel through the water at 1450 m/s. The ocean bottom is 1630 m below the surface. Determine the amount of time that passes before the sound waves are reflected back to the surface.

**Problem 7:**

aa. The intensity of sound waves decreases as the distance from the source of sound increases. The relationship between intensity (**I**) and distance (**d**) is an inverse square relationship which follows the equation **I = P/(4•π•R2)** where **P** is the power of the sound source, usually expressed in Watts. Jake recently purchased a stereo system for his basement recreation room. Determine the maximum intensity of the sound waves at the following distances from his 120-Watt main speaker.

a. 1.0 meter

b. 2.0 meter

c. 3.0 meter

**Problem 8:**

aa. Determine the decibel rating of the following sound sources and their estimated sound intensities.

a. Science office at 5 PM on a weeknight: I = ~1 x 10-9 W/m2

b. South's student library after school: I = ~1 x 10-6 W/m2

c. Period 7 at the beginning of class: I = ~1 x 10-4 W/m2

d. Titan Dome on a Friday night during basketball season: I = 8.1 x 10-3 W/m2

e. Fall Out Boy concert - front row: I = 7.4 x 10-2 W/m2

**Problem 9:**

aa. For the following decibel levels, determine the corresponding sound intensity levels in W/m2.

a. 50 dBel

b. 90 dBel

c. 110 dBel

**Problem 10:**

aa. According to Guinness, the record for the loudest burp is held by Paul Hunn of London. In September of 2008, his burp was measured at 107.1 dB, Determine the intensity in W/m2 of Paul's burp.

**Problem 11:**

aa. Mr. H recently purchased a home four blocks from the busy tollway. On a typical evening, the decibel level resulting from tollway traffic is 62 dB at the location of his house. Determine the decibel level on the same evening at a house 1 block from the tollway (four times closer).

**Problem 12:**

aa. During a Variety Show practice, Jake plucked a string on his guitar, sending vibrations through it in both directions. The string is pulled to a tightness of 220 N and has a mass density of 0.013 kg/m. Determine the speed with which vibrations travel through the string.

**Problem 13:**

aa. During the Pluck It! Lab, lab partners Anna Litical and Noah Formula determined the speed of vibrations through a 2.45-meter length of wire. The wire had a mass of 19.5 grams. If the speed was measured to be 253 m/s, determine the tension to which it was pulled.

**Problem 14:**

aa. In a demonstration, Mr. H stretches a steel wire to a length 1.23 meters and braces both ends so that they are not free to vibrate. He attaches a fancy piece of equipment that he calls a *mechanical oscillator* to the wire and explains how it works. Then Mr. H turns the oscillator on and tunes the frequency to 588 Hz. To the amazement of the class, the wire begins vibrating in the sixth harmonic wave pattern.

a. Determine the speed of waves within the wire.

b. Determine the frequency at which the wire will vibrate with the first harmonic wave pattern.

c. Determine the frequency at which the wire will vibrate with the second harmonic wave pattern.

**Problem 15:**

aa. Olivia and Mason are doing a lab that involves stretching an elastic cord between two poles that are 98 cm apart. They use a mechanical oscillator to force the cord to vibrate with the third harmonic wave pattern when the frequency is 84 Hz. Determine the speed of vibrations within the elastic cord.

**Problem 16:**

aa. A 1.65-meter length string is forced to vibrate in its fifth harmonic. Determine the locations of the nodal positions. Express the locations as a distance measured from one of the ends of the string.

**Problem 17:**

aa. A steel piano wire is pulled to a tension of 448 N and has a mass density of 0.00621 kg/m. The string is 61.8 cm long and vibrates at its fundamental frequency.

a. Determine the speed at which vibrations travel through the wire.

b. Determine the wavelength of the standing wave pattern for the fundamental frequency.

c. Determine the frequency of its vibrations.

**Problem 18:**

aa. A steel piano wire is 72.9 cm long and has a mass of 4.54 x 10-3 kg. The fundamental frequency of the wire is 262 Hz, corresponding to the frequency of middle C on the musical scales. Determine the tension to which the wire is pulled in order to vibrate with this frequency.

**Problem 19:**

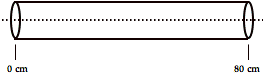
aa. In the singing rod demonstration, Mr. H holds a 2.13-m length of aluminum rod in the exact center. With rosin on his fingers, he slides his sticky fingers back and forth over the rod until it begins to *sing out* with a very pure tone. Assuming waves travel at speeds of 6320 m/s within the aluminum and that the standing wave pattern is characteristic of one-half wavelength between the rod's ends, determine the frequency of the sound.

**Problem 20:**

aa. Two strings made of the same material (same mass density) and stretched to the same tension (and thus, having the same speed) have a different length. One of the strings is 80-cm long (**String A**) and the other string is 60 cm (**String B**). They are vibrated at various frequencies in order to establish standing wave patterns within them. Consider the first six harmonics of the two strings. Which harmonic of String A would have the same frequency as one of the harmonics of String B?

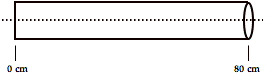
**Problem 21:**

aa. An 80-cm length open-end air column is forced to vibrate in its fifth harmonic. Determine the locations of the nodal positions (positions where air is undisturbed). Express the locations in cm using the diagram below.



**Problem 22:**

aa. An 80-cm length closed-end air column is forced to vibrate in its fifth harmonic. Determine the locations of the nodal positions (positions where air is undisturbed). Express the locations in cm using the diagram below. Note that the closed end is at 0 cm.



**Problem 23:**

aa. An organ pipe which acts as a open-end resonator has a length of 83 cm. Its fundamental frequency is 210 Hz.

a. Determine the speed of sound waves in the air column of the pipe.

b. Determine the frequency of the second, third and fourth harmonics of the organ pipe.

**Problem 24:**

aa. An organ pipe that acts as a closed-end resonator has a length of 83 cm. Sound waves travel at 350 m/s through the air column of the pipe.

a. Determine the fundamental frequency of the organ pipe.

b. Determine the frequency of the next two harmonics of this closed-end organ pipe.

**Problem 25:**

aa. Middle C on a piano keyboard corresponds to a frequency of 262 Hz. Determine the length of an open-end air column whose fundamental matches this frequency. Use a value of 348 m/s as the speed of sound.

**Problem 26:**

aa. In the Speed of Sound Lab, Anna Litical and Noah Formula partially submerge a plastic tube into a column of water. The water air interface causes the tube to be a closed-end air column. Holding a 384-Hz tuning fork above the tube, they find that they must adjust the length of air within the air column to 22.6 cm in order to force the air column into resonance vibration with the tuning fork. Determine the speed of sound in the air column.

**Problem 27:**

aa. A musical recorder acts as an open-end air column, with a vibrational antinode located at the hole near the mouthpiece (known as the windway hole) and a vibrational antinode located at the nearest open tone hole. Blowing gently on the mouthpiece will force the air column to vibrate at its fundamental frequency. Assuming a speed of sound of 345 m/s, what length of air would be required to cause the recorder to sound out at 1050 Hz?

**Problem 28:**

aa. A 2.29-m long organ pipe acts as a closed-end resonator that produces several different harmonic frequencies in the audible range from 20 Hz to 20,000 Hz. Assuming a speed of sound of 343 m/s, determine the 5th highest frequency that the pipe can produce.

**Problem 29:**

aa. The fundamental frequency of an open-end organ pipe is 392 Hz. The third harmonic of a closed-end organ pipe has the same frequency. The speed of sound in air is 346 m/s.

a. Determine the length of the open-end pipe.

b. Determine the length of the closed-end pipe.

**Problem 30:**

aa. Haley and Ariel are working on their Musical Instruments Project. They are creating a *Pop Bottle Orchestra* using a collection of pop bottles filled with water to varying heights. By blowing over the top of the pop bottles, the air column inside acts as a closed-end air column with the water surface at the bottom forcing a vibrational node within the standing wave pattern. Each bottle is 34.2-cm tall. Assuming a speed of sound of 345 m/s and a first harmonic wave pattern, determine how much water must be in the bottle in order for it to produce a 416 Hz sound wave.

**Problem 31:**

aa. South's orchestra walk on stage, take their seats and attempt to tune all instruments to 440 Hz - the A note of the oboe. Elizabeth tunes the A-string of her violin to the oboe. At one point in the process, she detects beats of 2 Hz between her string and the oboe. If her string is playing too low of a pitch, then what is its frequency?

**Problem 32:**

aa. Marc is attempting to tune his guitar. After adjusting his E4 string to 330 Hz, he begins to tackle the B3 string. In the process, he plucks both strings simultaneously and notices beats occurring at a rate of 12 beats in 4 seconds. When plucked individually, Marc observes the B3 string to sound out at a higher pitch. What is the frequency of the B3 string?