GPN1-LS11

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Problem 1

The Normal Temperature and Pressure(NTP) is defined as air at 20°C (293.15 K) and 1 atm(=101.325 kPa). At sea level and under normal atmospheric conditions, the speed of sound is 343 m/s. A stone is dropped into a well. The splash is heard 3.00 s later. What is the depth of the well? (01小題)

the depth of the well=_______ m

01: **ANS:=40.7**

$$t_1=\sqrt{\frac{2h}{g}},\quad t_2=\frac{h}{343}$$

$$t_1+t_2=3,\quad \sqrt{\frac{2h}{g}}+\frac{h}{343}=3$$

$$\frac{2h}{g}=\left(3-\frac{h}{343}\right)^2=9-\frac{6h}{343}+\frac{h^2}{343^2}$$

$$h^2-6(343)h-\frac{343^2}{4.9}h+9(343)^2=0$$

2058 24010 1058841

$$\frac{26068\pm\sqrt{26068^2-4(1058841)}}{2}=40.68$$

$$t_1=2.882$$

$$t_2=0.119$$

Problem 1

Earthquakes generate sound waves inside Earth. Unlike a gas, Earth can experience both transverse (S) and longitudinal (P) sound waves. Typically, the speed of S waves is about 4.5 km/s, and that of P waves 8.0 km/s. A seismograph records P and S waves from an earthquake. The first P waves arrive 3.0 min before the first S waves. If the waves travel in a straight line, how far away does the earthquake occur? (01小題)

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the distance=_____ m

02: **ANS:=1.9E6**

$v_s = 4.5\times10^3$

$v_p = 8.0\times10^3$

$L = v_s t_s = v_p t_p \;,\; \tau = 180$

$t_s = t_p + 3\times60 = t_p + 180$

$v_s(t_p+\tau) = v_p t_p$

$\frac{t_p+\tau}{t_p} = \frac{v_p}{v_s} = \frac{8}{4.5} = 1.778$

$1+\frac{180}{t_p} = 1.778 \;,\; t_p = 231.4$

$L = 8\times10^3(231.4) = 1851\ \text{km}$

Problem 2

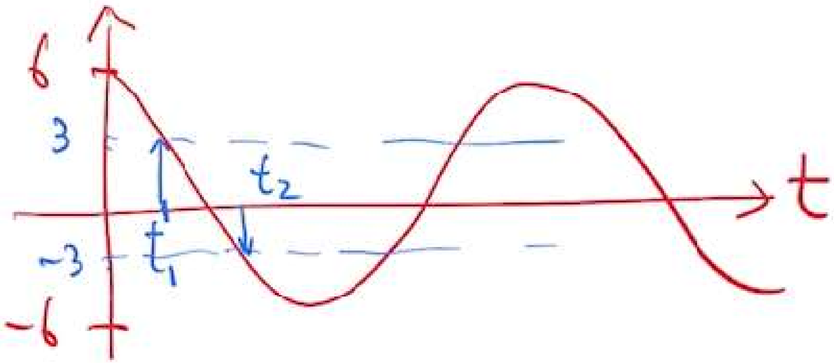
If the form of a sound wave traveling through air is

$$s(x,t) = (6.0nm)\cos(kx + (3000rad/s)t + \phi)),$$

how much time does any given air molecule along the path take to move between displacements s=+2.0 nm and s=-2.0 nm? (01小題)

(a)Δt=_____ s

03: **ANS:=0.23E-3**



$$s(t_1) = S_m \cos\omega t_1 = \frac{S_m}{3}$$

$$s(t_2) = S_m \cos\omega t_2 = -\frac{S_m}{3}$$

$$\cos\omega t_2 = -\frac{1}{3}, \quad \omega t_2 = \cos^{-1}\left(-\frac{1}{3}\right)$$

$$\cos\omega t_1 = \frac{1}{3}, \quad \omega t_1 = \cos^{-1}\frac{1}{3}$$

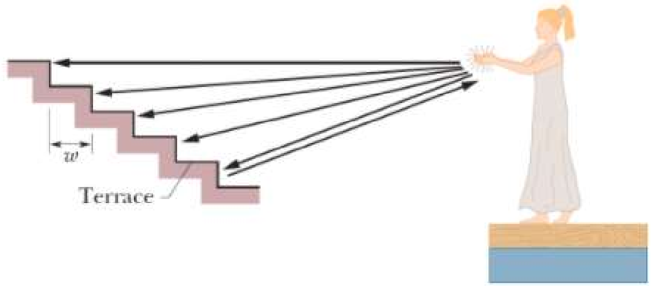
$$t_2 - t_1 = \frac{1}{\omega}\left[\cos^{-1}\left(-\frac{1}{3}\right) - \cos^{-1}\left(\frac{1}{3}\right)\right]$$

$$= \frac{1}{3000}(109.5^\circ - 70.5^\circ)\frac{\pi}{180}$$

$$= 2.27\times10^{-4}\ (s)$$

Problem 3

A handclap on stage in an amphitheater sends out sound waves that scatter from terraces of width $w = 0.75$ m (figure). The sound returns to the stage as a periodic series of pulses, one from each terrace; the parade of pulses sounds like a played note. (a) Assuming that all the rays in the figure are horizontal, find the frequency at which the pulses return (that is, the frequency of the perceived note). (01小題)



f=______ Hz

04: **ANS:=230**

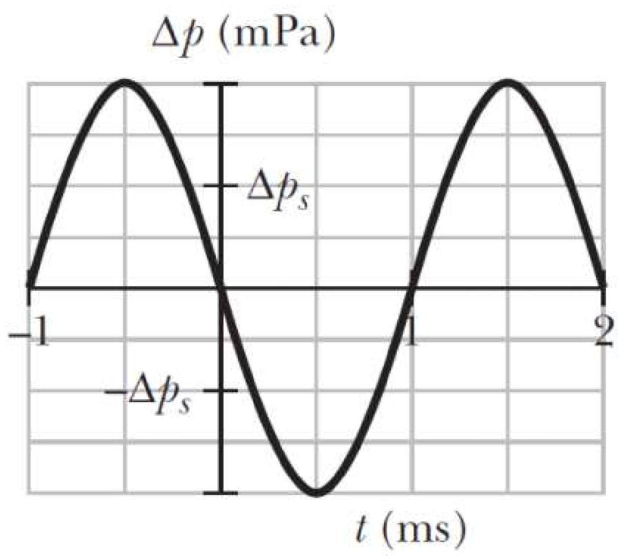
(a) Consider a string of pulses returning to the stage. A pulse which came back just before the previous one has traveled an extra distance of $2w$, taking an extra amount of time $\Delta t = 2w/v$. The frequency of the pulse is therefore

$$f = \frac{1}{\Delta t} = \frac{v}{2w} = \frac{343\,\text{m/s}}{2(0.75\,\text{m})} = 2.3\times10^2\ \text{Hz}.$$

(b) Since $f \propto 1/w$, the frequency would be higher if w were smaller.

Problem 4

The figure shows the output from a pressure monitor mounted at a point along the path taken by a sound wave of a single frequency traveling at 343 m/s through air with a uniform density of 1.21 kg/m^3. The vertical axis scale is set by $\Delta p_s = 4.0$ mPa. If the displacement function of the wave is written as $s(x,t) = s_m \cos(kx - \omega t)$, what are (a) s_m, (b) k, and (c)ω? The air is then cooled so that its density is 1.35 kg/m^3 and the speed of a sound wave through it is 320 m/s. The sound source again emits the sound wave at the same frequency and same pressure amplitude. What now are (d) s_m, (e) k, and (f)ω? (06小題)



(a)s_m=______ m

05: **ANS:=6.1E-9**

(b)k=______ rad/m

06: **ANS:=9.2**

07: **ANS:=3142**

(d)s_m=______ m

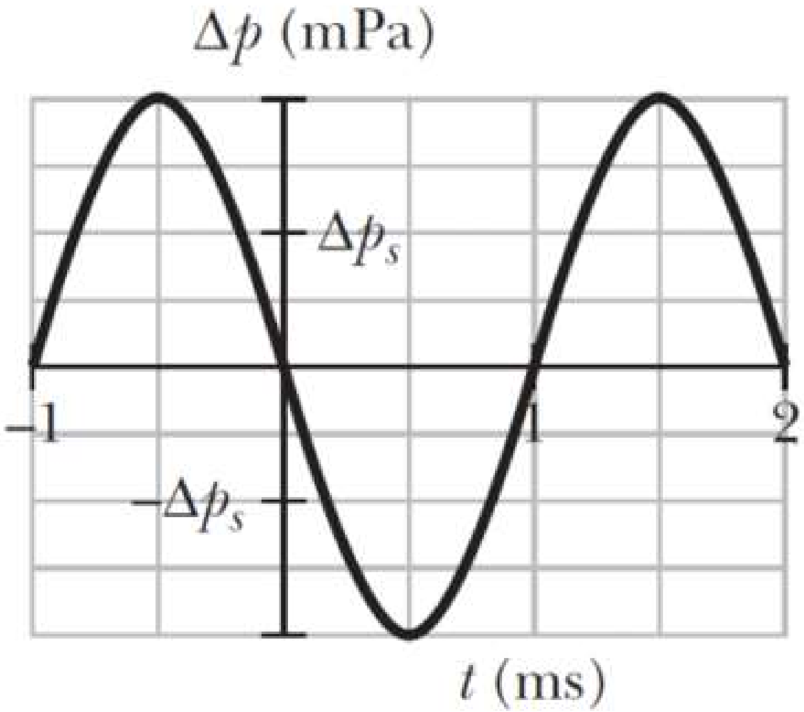
08: **ANS:=5.9E-9**

(e)k=______ rad/m

09: **ANS:=9.8**

(f)ω=______ rad/s

10: **ANS:=3142**



$$s(x,t) = s_m \cos(kx - \omega t)$$

take $x=0 \Rightarrow s(t) = s_m \cos(-\omega t)$

$$= s_m \cos \omega t$$

s_m is the amplitude of $s(t)$ graph

$$\Delta P_m = 2\Delta p_s = 2(4) = 8 \text{ mPa}$$

$$T = 2 \text{ ms} \Rightarrow \omega = \frac{2\pi}{T} = 3.14 \times 10^3$$

$$s_m = \frac{\Delta P_m}{v \rho \omega} = \frac{8 \times 10^{-3}}{(343)(1.21)(3.14 \times 10^3)} = 6.14 \times 10^{-9}$$

$$s(x,t) = 6.1 \times 10^{-9} \cos[9.16x - (3.14 \times 10^3)t]$$

emits the sound wave at the same
frequency and same pressure amplitude

$$s_m = \frac{\Delta p_m}{v' \rho' \omega} = 5.9 \times 10^{-9}$$

$$k = \omega v' = (3.14 \times 10^3)(320) = 5.9 \times 10^9$$

$$\omega' = \omega = 3.14 \times 10^3$$

Problem 5

Two sound waves, from two different sources with the same frequency, 540 Hz, travel in the same direction at 330 m/s. The sources are in phase. What is the phase difference of the waves at a point that is 4.40 m from one source and 4.00 m from the other? (01小題)

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the phase difference, $\Delta\phi$=______ rad

11: **ANS:=<u>4.12</u>**

Let the separation between the point and the two sources (labeled 1 and 2) be x_1 and x_2, respectively. Then the phase difference is

$$\Delta\phi = \phi_1 - \phi_2 = 2\pi\left(\frac{x_1}{\lambda} + ft\right) - 2\pi\left(\frac{x_2}{\lambda} + ft\right) = \frac{2\pi(x_1 - x_2)}{\lambda} = \frac{2\pi(4.40\,\text{m} - 4.00\,\text{m})}{(330\,\text{m/s})/540\,\text{Hz}} = 4.12\,\text{rad}.$$

Problem 6

The figure shows two isotropic point sources of sound, S_1 and S_2. The sources emit waves in phase at wavelength 0.50 m; they are separated by $D = 1.75$ m. If we move a sound detector along a large circle centered at the midpoint between the sources, (a)at how many points does the detector finds loud sound? (b)the least angle between +x and the line to the loud point. (02小題)

(a)the number of loud sound points on the large circle=_____

12: **ANS:=<u>14</u>**

(b)the least angle=____ rad

13: **ANS:=<u>1</u>**

(a) The problem is asking at how many angles will there be "loud" resultant waves, and at how many will there be "quiet" ones? We note that at all points (at large distance from the origin) along the x axis there will be quiet ones; one way to see this is to note that the path-length difference (for the waves traveling from their respective sources) divided by wavelength gives the (dimensionless) value 3.5, implying a half-wavelength (180°) phase difference (destructive interference) between the waves. To distinguish the destructive interference along the $+x$ axis from the destructive interference along the $-x$ axis, we label one with +3.5 and the other –3.5. This labeling is useful in that it suggests that the complete enumeration of the quiet directions in the upper-half plane (including the x axis) is: –3.5, –2.5, –1.5, –0.5, +0.5, +1.5, +2.5, +3.5. Similarly, the complete enumeration of the loud directions in the upper-half plane is: –3, –2, –1, 0, +1, +2, +3. Counting also the "other" –3, –2, –1, 0, +1, +2, +3 values for the *lower*-half plane, then we conclude there are a total of $7 + 7 = 14$ "loud" directions.

(b) The discussion about the "quiet" directions was started in part (a). The number of values in the list: –3.5, –2.5, –1.5, –0.5, +0.5, +1.5, +2.5, +3.5 along with –2.5, –1.5, –0.5, +0.5, +1.5, +2.5 (for the lower-half plane) is 14. There are 14 "quiet" directions.

Problem 7

Two loudspeakers are located 3.35 m apart on an outdoor stage. A listener is 18.3 m from one and 19.5 m from the other. During the sound check, a signal generator drives the two speakers in phase with the same amplitude and frequency. The transmitted frequency is swept through the audible range (20 Hz to 20 kHz). (a) What is the lowest frequency $f_{min,1}$ that gives minimum signal (destructive interference) at the listener's location? By what number must $f_{min,1}$ be multiplied to get (b) the second lowest frequency $f_{min,2}$ that gives minimum signal and (c) the third lowest frequency $f_{min,3}$ that gives minimum signal? (d) What is the lowest frequency $f_{max,1}$ that gives maximum signal (constructive interference) at the listener's location? By what number must $f_{max,1}$ be multiplied to get (e) the second lowest frequency $f_{max,2}$ that gives maximum signal and (f) the third lowest frequency $f_{max,3}$ that gives maximum signal? (06小題)

(a) $f_{min,1}$=______ Hz

14: **ANS:=143**

(b) $f_{min,2}$=______ $f_{min,1}$

15: **ANS:=3**

(c) $f_{min,3}$=______ $f_{min,1}$

16: **ANS:=5**

(d) $f_{max,1}$=______ Hz

17: **ANS:=286**

(e) $f_{max,2}$=______ $f_{max,1}$

18: **ANS:=2**

(f) $fmax,3$=______ $f_{max,1}$

19: **ANS:=3**

$\Delta L = (19.5 - 18.3)$ m $= 1.2$ m.

Problem 7
Two loudspeakers are located 3.35 m apart

$$v = f\lambda, \qquad f_{\min,n} = \frac{(2n-1)v}{2\Delta L} = (n - 1/2)(286 \text{ Hz})$$

$$v = 343 \text{ m/s}$$

(a) The lowest frequency that gives destructive interference is ($n = 1$)

$$f_{\min,1} = (1 - 1/2)(286 \text{ Hz}) = 143 \text{ Hz}.$$

(b) The second lowest frequency that gives destructive interference is ($n = 2$)

$$f_{\min,2} = (2 - 1/2)(286 \text{ Hz}) = 429 \text{ Hz} = 3(143 \text{ Hz}) = 3 f_{\min,1}.$$

(c) The third lowest frequency that gives destructive interference is ($n = 3$)

$$f_{\min,3} = (3 - 1/2)(286 \text{ Hz}) = 715 \text{ Hz} = 5(143 \text{ Hz}) = 5 f_{\min,1}.$$

in order to establish constructive interference. $\Delta L / \lambda = \frac{1}{2}$ (even numbers)

$$f_{\max,n} = \frac{nv}{\Delta L} = n(286 \text{ Hz}).$$

(d) The lowest frequency that gives constructive interference is ($n = 1$) $f_{\max,1} = (286 \text{ Hz})$.

(e) The second lowest frequency that gives constructive interference is ($n = 2$)

$$f_{\max,2} = 2(286 \text{ Hz}) = 572 \text{ Hz} = 2 f_{\max,1}.$$

(f) The third lowest frequency that gives constructive interference is ($n = 3$)

$$f_{\max,3} = 3(286 \text{ Hz}) = 858 \text{ Hz} = 3 f_{\max,1}.$$

Problem 8

A 1.0 W point source emits sound waves isotropically. Assuming that the energy of the waves is conserved, find the intensity (a) 1.0 m from the source and (b) 2.5 m from the source. (02小題)

(a)1.0 m from the source, the intensity=_____ W/m2

20: **ANS:=0.08**

(b)2.5 m from the source, the intensity=_____ W/m2

21: **ANS:=0.013**

(a) Since intensity is power divided by area, and for an isotropic source the area may be written $A = 4\pi r^2$ (the area of a sphere), then we have

$$I = \frac{P}{A} = \frac{1.0\,\text{W}}{4\pi(1.0\,\text{m})^2} = 0.080\,\text{W/m}^2.$$

(b) This calculation may be done exactly as shown in part (a) (but with $r = 2.5$ m instead of $r = 1.0$ m), or it may be done by setting up a ratio. We illustrate the latter approach. Thus,

$$\frac{I'}{I} = \frac{P/4\pi(r')^2}{P/4\pi r^2} = \left(\frac{r}{r'}\right)^2$$

leads to $I' = (0.080\ \text{W/m}^2)(1.0/2.5)^2 = 0.013\ \text{W/m}^2$.