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Chapter 16 In-Class Problems

Ex. 1

Example 16.1 (in Section 16.1) showed that for sound waves in with frequency 1,000 Hz $A = 1.2\times10^{-8}$ m $\rightarrow P_0 = 3.0\times10^{-2}$ Pa

a.) $\lambda = ?$ P_0 = pressure amplitude (or P_{max}) $= BkA = B\left(\frac{2\pi}{\lambda}\right)A$

$$\lambda = 2\pi BA/P_0 = \frac{2\pi(1.42\times10^{5}\ \text{Pa})(1.2\times10^{-8}\ \text{m})}{3.0\times10^{-2}\ \text{Pa}}$$

$\boxed{\lambda = 0.357\ \text{m}}$ $\lambda = \frac{v}{f} = 0.344$ m

b.) for 1,000 Hz waves in air, $P_{max} = BkA = 30$ Pa

$A = ?$ $A = \frac{30\ \text{Pa}\ (0.357\ \text{m})}{(1.42\times10^{5}\ \text{Pa})\ 2\pi}$ $\boxed{A = 1.20\times10^{-5}\ \text{m}}$ ✓

c.) $\lambda = ?$ $f = ?$ when $A = 1.2\times10^{-8}$ m and $BkA = 1.5\times10^{-3}$ Pa

$BkA = B\left(\frac{2\pi}{\lambda}\right)A = 1.5\times10^{-3}$ Pa $\lambda = \frac{2\pi(1.42\times10^{5}\ \text{Pa})(1.2\times10^{-8}\ \text{m})}{1.5\times10^{-3}\ \text{Pa}}$

$\boxed{\lambda = 7.14\ \text{m}}$ $f = \frac{v}{\lambda} = \frac{344\ \text{m/s}}{7.14\ \text{m}}$ $\boxed{f = 48.2\ \text{Hz}}$

$\lambda = 6.9$ m $f = 50$ Hz

Ex. 10

Show that the fractional change in the speed of sound (dv/v) due to a very small temperature change dT...

$\frac{dv}{v} = \frac{1}{2}\frac{dT}{T}$ T = temperature

$$v = \sqrt{\frac{\gamma RT}{M}} \qquad dv = \sqrt{\frac{\gamma R}{M}}\left(\tfrac{1}{2}T^{-1/2}dT\right)$$

$$\frac{dv}{v} = \frac{\sqrt{\gamma R/M}\ T^{-1/2}\left(\frac{1}{2}\right)dT}{\sqrt{\gamma R/M}\ T^{1/2}} = \boxed{\frac{1}{2}\frac{dT}{T}}$$

b.) $T = 20°C \rightarrow v_{air} = 344$ m/s $dT = 1C°$

$dv = ?$ $dv = \frac{1}{2}v\frac{dT}{T} = \frac{1}{2}(344\ \text{m/s})\left(\frac{1\ C°\ (K)}{293\ °K}\right)$ 20°C

$\boxed{dv = 0.587\ \text{m/s}}$

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Ex. 15 A sound wave in air at 20°C has a frequency of 320 Hz. $A = 5.00 \times 10^{-3}$ mm.

a.) $P_{max} = ?$ $\quad P_{max} = BkA = B\dfrac{2\pi}{\lambda} A = 2\pi BA\dfrac{f}{v}$ $\quad \lambda = v/f$

$$P_{max} = \frac{2\pi(1.42\times10^{5}\,\text{Pa})(5.00\times10^{-6}\,\text{m})(320\,\text{s}^{-1})}{344\,\text{m/s}} = \boxed{4.15\ \text{W}}$$

b.) $I_{Av} = ?$ $\quad I_{Av} = \frac{1}{2} B k A^2 \omega = \frac{1}{2} B\omega^2 A^2 / v$ $\quad (k = \omega/v)$

$$I_{Av} = \frac{1}{2}\frac{(1.42\times10^{5}\,\text{Pa})(2\pi(320)\,\text{s}^{-1})^2(5.00\times10^{-6}\,\text{m})^2}{344\,\text{m/s}}$$

$$\boxed{I_{Av} = 2.09\times10^{-2}\ \text{W/m}^2}$$

c.) $\beta = ?$ The sound intensity $\quad \beta = 10\,\text{dB}\log_{10}\left(\dfrac{I_{Av}}{I_0}\right)$

$$\beta = 10\,\text{dB}\log_{10}\left(\frac{2.09\times10^{-2}}{1.0\times10^{-12}}\right) = 103\ \text{dB}$$

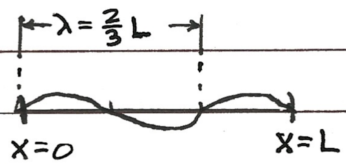
Ex. 27 The longest pipe found in most medium-size pipe organs is 4.88 m (16 ft) long. $f_1 = ?$ if

a.) "Open" $\quad f_n = \dfrac{nv}{2L} \quad f_1 = \dfrac{v}{2L} = \dfrac{344\,\text{m/s}}{2(4.88\,\text{m})} \quad \boxed{f_1 = 35.2\ \text{Hz}}$

b.) "Closed" $\quad f_n = \dfrac{nv}{4L} \quad f_1 = \dfrac{v}{4L} = \dfrac{344\,\text{m/s}}{4(4.88)\,\text{m}} \quad \boxed{f_1 = 17.6\ \text{Hz}}$

Ex. 30 You have a stopped pipe of adjustable length close to a taut wire under a tension of 4110 N. $\mu = \dfrac{7.25\,\text{g}}{62\,\text{cm}} = 1.17\times10^{-2}$ kg/m

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{4110\,\text{N}}{1.17\times10^{-2}\,\text{kg/m}}} = 593\ \text{m/s}$$



$$f = \frac{v}{\lambda} = \frac{593\,\text{m/s}}{\frac{2}{3}(0.62\,\text{m})} = \underline{1435\ \text{Hz}}$$

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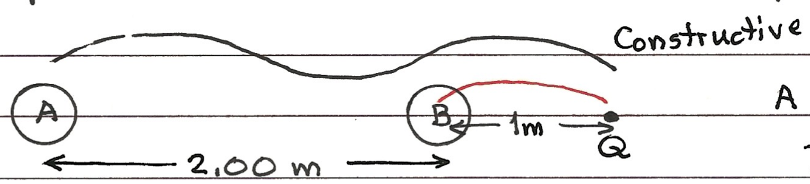
Ex. 30 cont'd $f = 1435\ \text{Hz}$

Stopped Organ Pipe → $f_1 = \dfrac{v}{4L}$ $\quad L = \dfrac{v}{4f_1} = \dfrac{344\ \text{m/s}}{4(1435\ \text{Hz})} = \boxed{0.060\ \text{m}}$

Ex. 33 Two loudspeakers, A & B, are driven by the same amplifier and emit sinusoidal waves in phase.



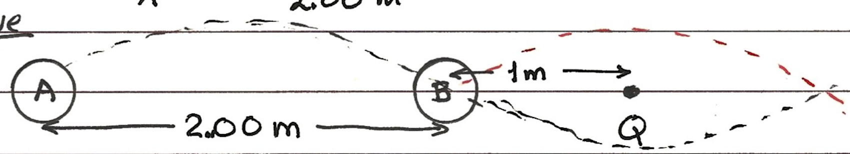
A full wavelength is $\lambda = 2.00\ \text{m}$.

This corresponds to the lowest f.

Constructive

$$f = \frac{v}{\lambda} = \frac{344\ \text{m/s}}{2.00\ \text{m}} = 172\ \text{s}^{-1} \qquad \boxed{f = 172\ \text{Hz}}\ \text{Constructive}$$

Destructive



$2.00\ \text{m} = n\dfrac{\lambda}{2}$ for destructive interference.

$\underline{n=1}$ $\quad \lambda = 4.00\ \text{m}$ $\quad f = \dfrac{v}{\lambda} = \dfrac{344\ \text{m/s}}{4.00\ \text{m}} = \boxed{86.0\ \text{Hz}}$ Destructive.

Ex. 40 Two organ pipes, open at one end but closed at the other, are each 1.14 meters long. One is now lengthened by 2.0 cm.

$f_1 = \dfrac{v}{4L_1}$ $\quad f_1' = \dfrac{v}{4L_2}$ $\quad f_1 = \dfrac{344\ \text{m/s}}{4(1.14\ \text{m})} = \underline{75.44\ \text{Hz}}$

$f_1' = \dfrac{344\ \text{m/s}}{4(1.16\ \text{m})} = \underline{74.14\ \text{Hz}}$ $\quad \boxed{|f_1 - f_1'| = 1.30\ \text{Hz}}$

Ex. 44 Moving Source vs. Moving Listener. A sound source producing 1.00 kHz waves moves toward a stationary listener

a.) at $\frac{1}{2}v$. $\quad f' = f\left(\dfrac{v \pm v_L}{v \mp v_S}\right) = 1.00\ \text{kHz}\left(\dfrac{v + 0}{v - \frac{1}{2}v}\right) = \underline{2.00\ \text{kHz}}$

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Ex. 44 Cont'd

b.) Source is stationary, and the listener moves toward the source at ½ v

$$f' = f\left(\frac{v \pm v_L}{v \mp v_s}\right) = 1.00\,\text{kHz}\left(\frac{v + \frac{1}{2}v}{v + 0}\right) = \frac{3}{2}(1.00\,\text{kHz})$$

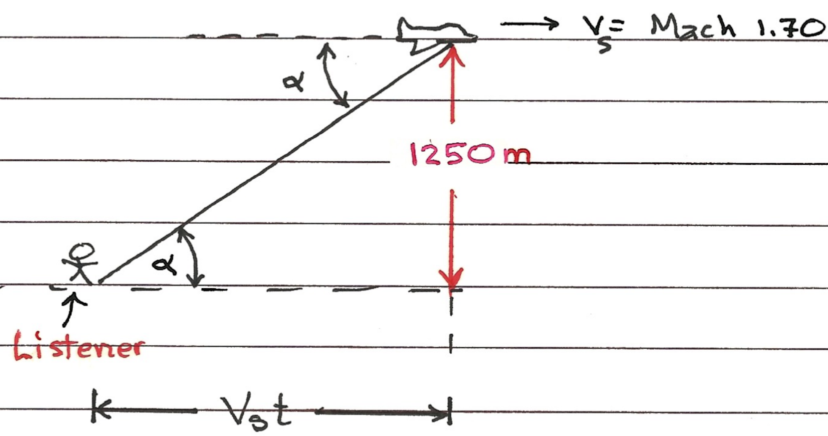
$f' = 1.50\,\text{kHz}$

Ex. 53 A jet plane flies overhead at Mach 1.70 at a constant altitude of 1250 m.

$$\sin\alpha = \frac{v}{v_s} = \frac{1}{1.7} \qquad \alpha = \sin^{-1}\left(\frac{1}{1.7}\right) = 36.0°$$

b.) How much time after the plane passes directly overhead do you hear the sonic boom?

$$\tan\alpha = \frac{1250\text{ m}}{v_s t}$$



$$t = \frac{1250\text{ m}}{v_s \tan\alpha} = \frac{1250\text{ m}}{1.70(344\text{ m/s})\tan 36.0°} = 2.94\text{ s}$$

$$\boxed{t = 2.94\text{ s}}$$

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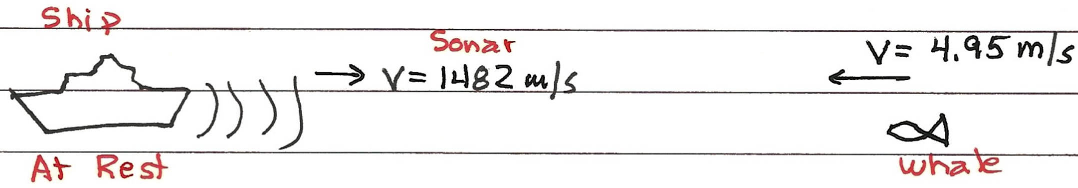
Ex. 63 The sound source of a ship's sonar system operates at a frequency of 18.0 kHz.

V = speed of sound in water = 1482 m/s

a.) $\lambda = ?$ $\quad \lambda = \dfrac{V}{f} = \dfrac{1482 \text{ m/s}}{18{,}000 \text{ s}^{-1}}$ $\quad \lambda = 0.0823 \text{ m}$

b.)



1.) The frequency received by the whale:

$$f' = f\left(\frac{V + V_L}{V + 0}\right) = 18{,}000 \text{ Hz}\left(\frac{1482 + 4.95}{1482}\right)$$

f' (received and bouncing off the whale) = 18,060 Hz

2.) Now, the whale is the new "source" of the sonar at a frequency of 18,060 Hz.

$$f' = f\left(\frac{V + 0}{V - V_s}\right) = 18{,}060 \text{ Hz}\left(\frac{1482}{1482 - 4.95}\right) = 18{,}121 \text{ Hz}$$

$$\Delta f = 18{,}121 \text{ Hz} - 18{,}000 \text{ Hz} = \boxed{121 \text{ Hz}}$$