

Chapter 16 In-Class Problems

DATE	
TOPIC	①

Ex. 1

Example 16.1 (in Section 16.1) showed that for sound waves in with frequency 1,000 Hz $A = 1.2 \times 10^{-8} \text{ m} \rightarrow P_o = 3.0 \times 10^{-2} \text{ Pa}$

a.) $\lambda = ?$ $P_o = \text{or } P_{\text{max}} = \text{pressure amplitude} = BkA = B \left(\frac{2\pi}{\lambda} \right) A$
 $\lambda = 2\pi BA / P_o = 2\pi (1.42 \times 10^5 \text{ Pa}) (1.2 \times 10^{-8} \text{ m}) / 3.0 \times 10^{-2} \text{ Pa}$

$\lambda = 0.357 \text{ m}$

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

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

$A = ?$ $A = 30 \text{ Pa} / \left((1.42 \times 10^5 \text{ Pa}) 2\pi \right) \rightarrow \lambda$ $A = 1.20 \times 10^{-5} \text{ m} \checkmark$

c.) $\lambda = ?$ $f = ?$ when $A = 1.2 \times 10^{-8} \text{ m}$ and $BkA = 1.5 \times 10^{-3} \text{ Pa}$

$BkA = B \left(\frac{2\pi}{\lambda} \right) A = 1.5 \times 10^{-3} \text{ Pa}$ $\lambda = \frac{2\pi (1.42 \times 10^5 \text{ Pa}) (1.2 \times 10^{-8} \text{ m})}{1.5 \times 10^{-3} \text{ Pa}}$

$\lambda = 7.14 \text{ m}$

$\lambda = 6.9 \text{ m}$

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

$f = 48.2 \text{ Hz}$

$f = 50 \text{ Hz}$

Ex. 10

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

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

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

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

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

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

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

$\swarrow 20^\circ\text{C}$

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Ex. 15

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

a.) $P_{\text{max}} = ?$ $P_{\text{max}} = B k A = B \frac{2\pi A}{\lambda} = 2\pi B A \frac{f}{v}$
 $\lambda = v/f$

$$P_{\text{max}} = 2\pi (1.42 \times 10^5 \text{ Pa}) (5.00 \times 10^{-6} \text{ m}) \frac{(320 \text{ s}^{-1})}{344 \text{ m/s}} = \boxed{4.15 \text{ Pa}}$$

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

$$I_{\text{AV}} = \frac{1}{2} (1.42 \times 10^5 \text{ Pa}) (2\pi(320 \text{ s}^{-1}))^2 \frac{(5.00 \times 10^{-6} \text{ m})^2}{344 \text{ m/s}}$$

$$\boxed{I_{\text{AV}} = 2.09 \times 10^{-2} \text{ W/m}^2}$$

c.) $\beta = ?$ The sound intensity $\beta = 10 \text{ dB} \log_{10} \left(\frac{I_{\text{AV}}}{I_0} \right)$

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

Ex. 27

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

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

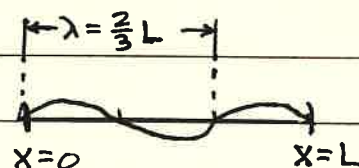
b.) "Closed" $f_n = \frac{n v}{4L}$ $f_1 = \frac{v}{4L} = \frac{344 \text{ m/s}}{4(4.88 \text{ m})}$ $\boxed{f_1 = 17.6 \text{ Hz}}$

Ex. 30

You have a stopped pipe of adjustable length close to a taut wire under a tension of 4110 N . $\mu = \frac{7.25 \text{ g}}{62 \text{ cm}} = 1.17 \times 10^{-2} \text{ kg/m}$

$$v = \sqrt{\frac{F}{\mu}} = \sqrt{\frac{4110 \text{ N}}{1.17 \times 10^{-2} \text{ kg/m}}} = 593 \text{ m/s}$$

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



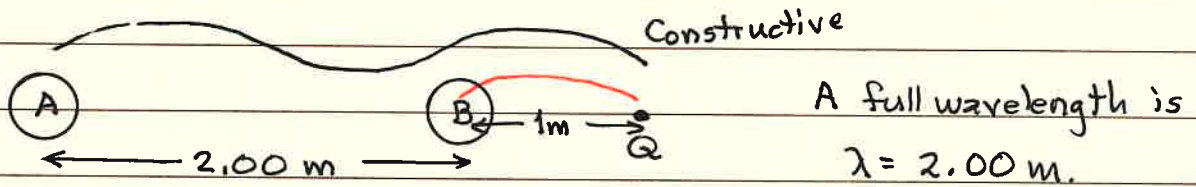
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Ex. 30 cont'd $f = 1435 \text{ Hz}$

Stopped Organ Pipe $\rightarrow f_1 = \frac{v}{4L}$ $L = \frac{v}{4f_1} = \frac{344 \text{ m/s}}{4(1435 \text{ Hz})} = 0.060 \text{ m}$

Ex. 33

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



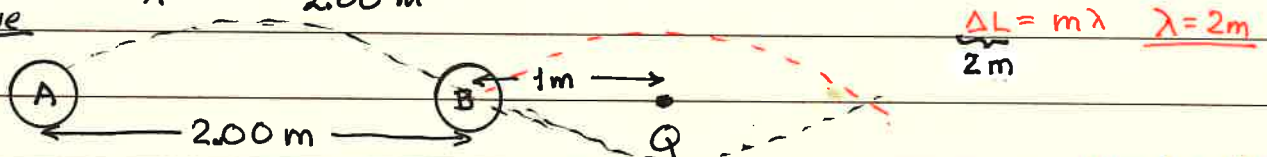
Constructive

This corresponds to the lowest f .

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

$f = 172 \text{ Hz}$ Constructive

Destructive



$2.00 \text{ m} = n \frac{\lambda}{2}$ for destructive interference. $\Delta L = (m + \frac{1}{2})\lambda$ $\lambda = 4m$

$n=1$ $\lambda = 4.00 \text{ m}$ $f = \frac{v}{\lambda} = \frac{344 \text{ m/s}}{4.00 \text{ m}} = 86.0 \text{ Hz}$ 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.

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

$$f_1' = \frac{344 \text{ m/s}}{4(1.16 \text{ m})} = 74.14 \text{ Hz}$$

$$|f_1 - f_1'| = 1.30 \text{ Hz}$$

Ex. 44

Moving Source vs. Moving Listener. A sound source producing 1.00 kHz waves moves toward a stationary listener at $\frac{1}{2}v$.

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

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Ex. 44 Cont'd

- b.) Source is stationary, and the listener moves toward the source at $\frac{1}{2}v$

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

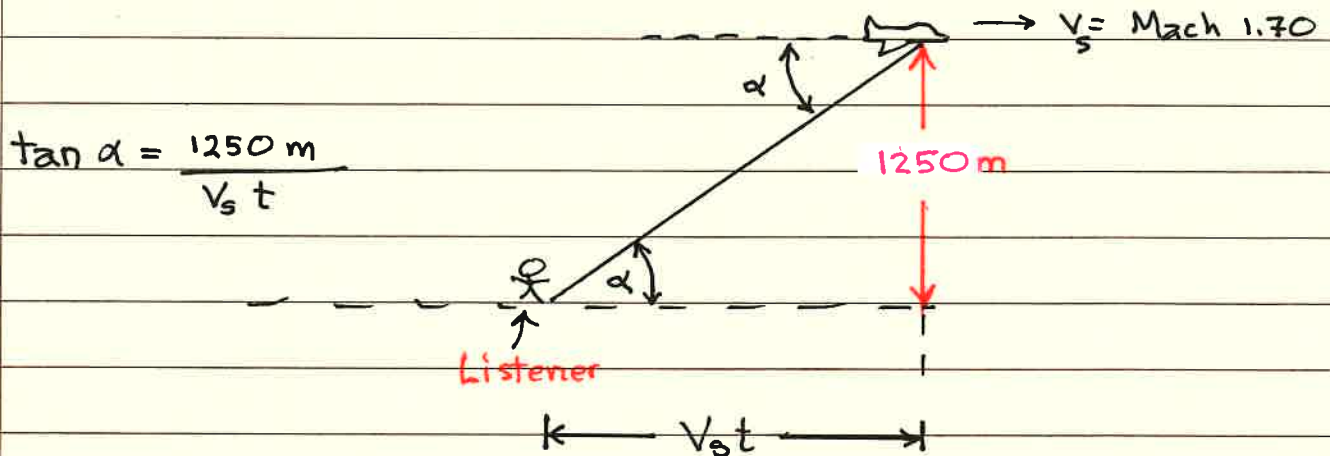
$$\underline{f' = 1.50 \text{ kHz}}$$

Ex. 53

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

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

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



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

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

$t = 2.94 \text{ s}$

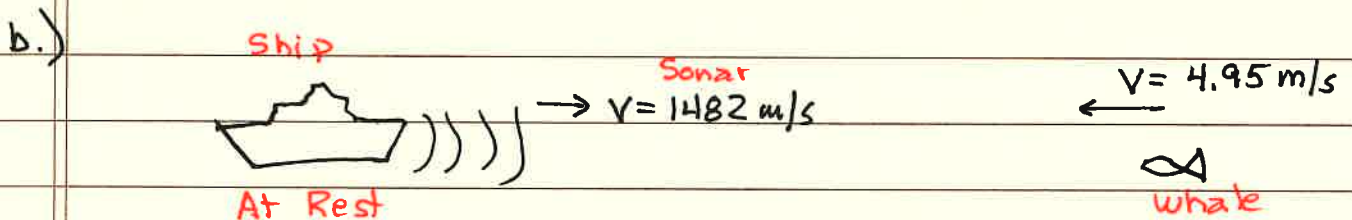
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Ex. 63

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



1.) The frequency received by the whale:

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

$$f' \text{ (received and bouncing off the whale)} = \underline{18,060 \text{ Hz}}$$

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

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

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