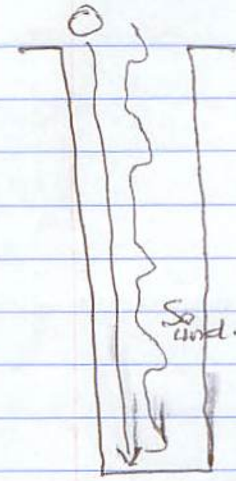
SOLNS – SET3

14-6 $T = 10^\circ C = 10 + 273 = 283K$




The speed of sound in air is

$$v = (331\,m/s)\sqrt{\frac{T}{273K}}$$

$$= (331\,m/s)\sqrt{\frac{283K}{273K}} = 337\,m/s$$

The elapsed time between when the stone was released and when the sound is heard is the sum of the time $t_1$ required for the stone to fall distance h and the time $t_2$ required for sound to travel distance h in air on the return up the well

$\Rightarrow t_1 + t_2 = 2\,sec$

The distance that stone falls in time $t_1 \equiv h = g\frac{t_1^2}{2}$

The time for sound to travel back up the well is $t_2$:

$$t_2 = \frac{h}{v} = \frac{gt_1^2}{2(337)} = \frac{gt_1^2}{674}$$

$\Rightarrow t_1 + t_2 = 2$

$$t_1 + \frac{gt_1^2}{674} = 2 \Rightarrow \left(\frac{g}{674}\right)t_1^2 + t_1 - 2 = 0$$

where $g = 9.8\,m/s^2$

SOLVE THE QUADRATIC IN $t_1$

$$t_1 = \frac{-1 \mp \sqrt{1-4(9.8/674)(-2)}}{2(9.8/674)}$$

$$\boxed{t_1 = 1.945\text{s}} \qquad t_1 = -70.72\text{ sec.}$$

$\Rightarrow t_1 = 1.945$ sec (only positive soln)

$\therefore$ Depth of the well is

$$h = \frac{g t_1^2}{2} = \frac{(9.8\text{ m/s}^2)(1.945\text{ s})^2}{2} = \boxed{18.5\text{m}}$$

14-7

From table 14.1;

speed of sound in saltwater is $v_w = 1530$ m/s

Speed of sound in air:

$$v_a = (331\text{ m/s})\sqrt{\frac{T}{273\text{K}}} = (331\text{ m/s})\sqrt{\frac{(20+273)\text{K}}{273\text{K}}} = 343\text{ m/s}$$

Transit time for sound in the water $= t_w = \frac{d}{v_w}$

$d =$ width of inlet

Transit time for sound in the air $= t_a = \frac{d}{v_a}$

$$\therefore t_a = t_w + 4.5 \Rightarrow \frac{d}{v_a} = \frac{d}{v_w} + 4.5$$

$$\Rightarrow \frac{d}{343\text{m/s}} = \frac{d}{1530\text{ m/s}} + 4.5 \Rightarrow d = \frac{(4.5)(v_w v_a)}{(v_w - v_a)}$$

$$\Rightarrow d = (4.5s)\left[\frac{(4530\ m/s)(343\ m/s)}{(1530-343)\ m/s}\right] = 1.99\times10^3 m$$
$$= \boxed{1.99 km}$$

14-10

$$A = 5\times10^{-5}\ m^2$$

The sound power is $P = IA$

(a) At the threshold of hearing, $I = 1\times10^{-12}\ W/m^2$

$$P = \left(1\times10^{-12}\ \frac{W}{m^2}\right)(5\times10^{-5}\ m^2) = \boxed{5\times10^{-17}\ W}$$

(b) At the threshold of pain, $I = 1\ W/m^2$

$$P = (1\ W/m^2)(5\times10^{-5}\ m^2) = \boxed{5\times10^{-5}\ W}$$

14-12

$$\beta_1 = 10\log\left(\frac{I_1}{I_0}\right) = 10\log\left(\frac{100\ W/m^2}{1\times10^{-12}\ W/m^2}\right) = 140\ dB$$

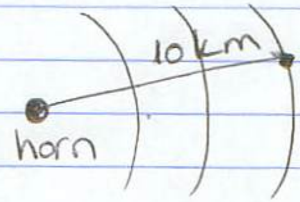
$$\beta_2 = 10\log\left(\frac{I_2}{I_0}\right) = 10\log\left(\frac{200\ W/m^2}{1\times10^{-12}\ W/m^2}\right) = 143.01\ dB$$

$$\Rightarrow \beta_2 - \beta_1 = 143.01\ dB - 140\ dB = \boxed{3.01\ dB}$$

14-15 $I = 4\ \mu\frac{W}{m^2} = 4\times10^{-6}\ W/m^2$

$$\beta = 10\log\left(\frac{I}{I_0}\right) = 10\log\left(\frac{4\times10^{-6}\ W/m^2}{1\times10^{-12}\ W/m^2}\right) = 10\log(4\times10^6)$$
$$= \boxed{66.02\ dB}$$

14-17




$\beta = 50\text{ dB}$

$r = 10\text{km} = 10\times10^{3}\text{ m}$

(a) $\beta = 10\log\left(\frac{I}{I_0}\right) \Rightarrow I = I_0 10^{\beta/10}$

$I = (1\times10^{-12}\text{ W/m}^2)(10^{50/10}) = 10^{-7}\text{ W/m}^2$

For a point source: $I = \frac{P}{4\pi r^2} \Rightarrow P = (I)(4\pi r^2)$

$P = (10^{-7}\text{ W/m}^2)(4\pi)(10\times10^{3}\text{m})^2$

$$\boxed{P = 1.3\times10^{2}\text{ W}}$$

(b) $r = 50\text{ m} \Rightarrow I = \frac{P}{4\pi r^2} = \frac{1.3\times10^{2}\text{ W}}{4\pi(50)^2} = 4\times10^{-3}\text{ W/m}^2$

Intensity level $\beta = 10\log\left(\frac{I}{I_0}\right) = 10\log\left(\frac{4\times10^{-3}\text{ W/m}^2}{1\times10^{-12}\text{ W/m}^2}\right)$

$$\boxed{\beta = 96\text{ dB}}$$

14-19 $\beta = 10\log\left(\frac{I}{I_0}\right) \Rightarrow \beta_1 = 10\log\left(\frac{I_1}{I_0}\right)$ and $\beta_2 = 10\log\left(\frac{I_2}{I_0}\right)$

$\beta_2 - \beta_1 = 10\left[\log\left(\frac{I_2}{I_0}\right) - \log\left(\frac{I_1}{I_0}\right)\right]$

[We know that $\log A - \log B = \log\frac{A}{B}$]

There fore

$$\beta_2 - \beta_1 = 10\log\left(\frac{(I_2/I_0)}{(I_1/I_0)}\right) = 10\log\left(\frac{I_2}{I_1}\right)$$

Since $I = \dfrac{P}{4\pi r^2}$

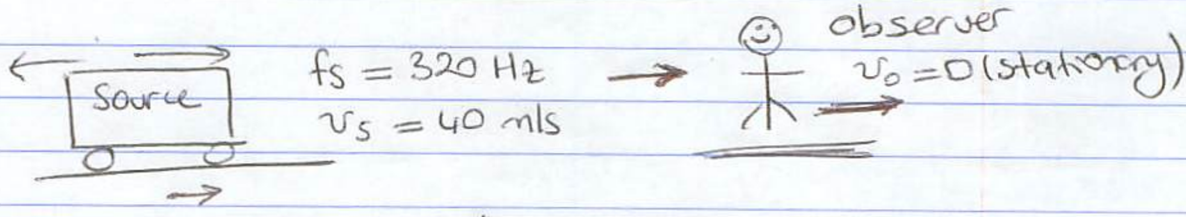
$$\frac{I_2}{I_1} = \frac{P/4\pi r_2^2}{P/4\pi r_1^2} = \frac{\cancel{P}}{4\pi r_2^2}\,\frac{4\pi r_1^2}{\cancel{P}} = \frac{r_1^2}{r_2^2}$$

Thus: $\beta_2 - \beta_1 = 10\log\left(\frac{I_2}{I_1}\right) = 10\log\left(\frac{r_1^2}{r_2^2}\right)$

$$= 10\log\left(\frac{r_1}{r_2}\right)^2$$

$$\beta_2 - \beta_1 = \boxed{20\log\left(\frac{r_1}{r_2}\right)}$$

14-21




(a) $f_o = f_s \dfrac{v}{v - v_s}$ ; Let motion be along x-axis

when the train is approaching, $\vec{v}_s = +40\,m/s\,\hat{x}$
After the train passes and is receding, $v_s = -40\,m/s\,\hat{x}$

$$(f_o)_{approach} = (320\,Hz)\,\frac{v}{v - 40}$$

We need to calculate the speed of sound in air. The book assumes that the ambient temperature is 24°C.

$$v = (331\,m/s)\sqrt{\frac{T}{273}} = 331\sqrt{\frac{(24+273)}{273}} = 345\,m/s$$

Then,

$$(f_o)_{approach} = (320\ Hz)\left(\frac{345\ m/s}{345\ m/s - 40\ m/s}\right) = 362\ Hz$$

$$(f_o)_{recede} = (320\ H_z)\left(\frac{v}{v-(-v_s)}\right)$$

$$= (320\ H_z)\left(\frac{345}{345-(-40)}\right)$$

$$= 287\ Hz$$

Thus, the frequency shift that occurs as the train passes is

$$\Delta f_o = (f_o)_{recede} - (f_o)_{approach}$$

$$= 287\ Hz - 362\ Hz = \boxed{-75.2\ Hz}$$

1(b)

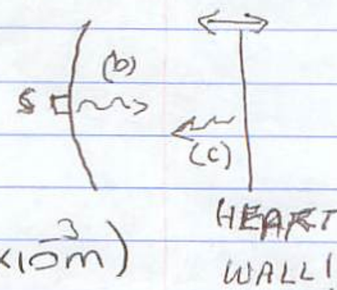
$$\lambda = \frac{v}{(f_o)_{approach}} = \frac{345\ m/s}{362\ Hz} = \boxed{0.953\ m}$$

14-26

$$A = 1.8\ mm = 1.8 \times 10^{-3}\ m$$

$$f = 115\ 1/min = 115\ \frac{1}{min}\ \frac{1}{60\ s/min} = 1.92\ \text{per second}$$

(a) For harmonic motion:




$$v_{max} = \omega A$$

$$\omega = 2\pi f$$

$$\Rightarrow v_{max} = 2\pi f A = 2\pi\,(1.92\ 1/sec)(1.8 \times 10^{-3} m)$$

$$= \boxed{0.0217\ m/s}$$

(b) For this case heart wall is a moving observer and the detector is a stationary source.

$$(f_{wall})_{heart} = f_s\left(\frac{v + v_{max}}{v}\right)$$

$$f_s = 2\ MHz = 2\times10^6\ Hz$$

$$v = 1.5\ \frac{km}{s} = 1.5\times10^3\ \frac{m}{s}$$

$$\Rightarrow (f_{wall})_{heart} = 2\times10^6\ Hz\ \frac{(1.5\times10^3\ \frac{m}{s} + 0.0217\ m/s)}{1.5\times10^3\ m/s}$$

$$= \boxed{2{,}000{,}029\ Hz}$$

(c) Now, the heart wall is a moving source and the detector is a stationary observer.

$$f_{echo} = (f_{wall})_{heart}\left(\frac{v}{v - v_{max}}\right)$$

$$= 2{,}000{,}029\ Hz\left(\frac{1500}{1500 - 0.0217}\right)$$

$$= \boxed{2{,}000{,}058\ Hz}$$

14-27 $f_s = 512\ Hz$

$f_o = 485\ Hz$

$f_o = f_s\left(\dfrac{v}{v-(-|v_s|)}\right)$ source is receding from a stationary observer

$f = f_s\left(\dfrac{v}{v+|v_s|}\right) \Rightarrow |v_s| = v\left(\dfrac{f_s}{f_o}-1\right)$

$= (340\ m/s)\left(\dfrac{512\ Hz}{485\ Hz}-1\right) = 18.9\ m/s$

The distance it has fallen from rest before reaching this speed is.

$$\Delta y_1 = \frac{v_s^2 - 0}{2a_y} = \frac{(18.9\ m/s)^2}{2\,(9.8\ m/s^2)} = 18.3\ m$$

The time required for 485 Hz sound to reach the observer is:

$$t = \frac{\Delta y_1}{v} = \frac{18.3m}{340\ m/s} = 0.0538 S$$

During this time fork falls an additional distance:

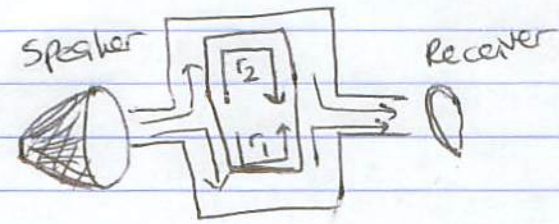
$$\Delta y_2 = v_s t + \frac{1}{2} a_y t^2 = (18.9)(0.0538) + \frac{1}{2}(9.8)(0.0538)^2$$

$$= \underline{1.03\ m}$$

$\therefore$ Total distance fallen before 485 Hz sound reaches the observer is:

$$\Delta y = \Delta y_1 + \Delta y_2 = 18.3m + 1.03m = \boxed{19.3m}$$

14-30




The book takes the speed of sound $v_s$ as 345 m/s.

The wavelength of the sound produced by the speaker is

$$\lambda = \frac{v}{f} = \frac{345\,m/s}{400\,Hz} = 0.863\,m$$

(a) If destructive interference is now occuring, one can increase the path length by $\frac{\lambda}{2}$ to produce constructive interference.

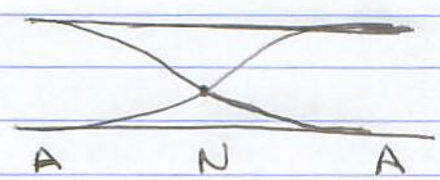
$$r_2 - r_1 = \left(n + \frac{1}{2}\right)\lambda \quad (n = 0, 1, 2 \ldots) \text{ destructive interference}$$

$$r_2 - r_1 = n\lambda \quad (n = 0, 1, 2, \ldots) \text{ constructive interference.}$$

$$\frac{\lambda}{2} = \frac{0.863}{2} = \boxed{0.431\,m}$$

(b) With destructive interference currently taking place, one can increase the path length by a full wavelength $\boxed{\lambda = 0.863\,m}$ to produce destructive interference again.

14-36




$L = 1\,m$

$$L = \frac{\lambda}{2} \Rightarrow \lambda = 2L = 2(1\,m) = 2\,m$$

The speed of sand in aluminum is $v = 5100$ m/s.
(see Table 14.1 in the textbook)

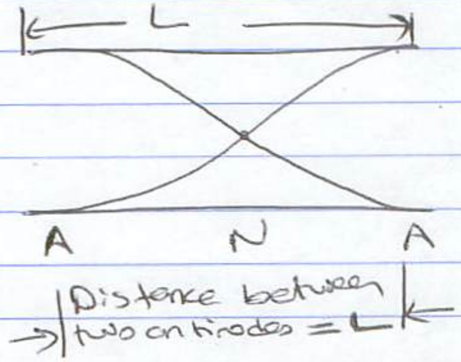
$$f = \frac{v}{\lambda} = \frac{5100\,\text{m/s}}{2\,\text{m}} = \boxed{2.55 \times 10^{3}\,\text{Hz}}$$

14-44

(a) In the fundamental resonant mode of a pipe open at both ends,

$$f_1 = \frac{v}{2L} = \frac{340\,\text{m/s}}{2(0.320\,\text{m})} = \boxed{531\,\text{Hz}}$$

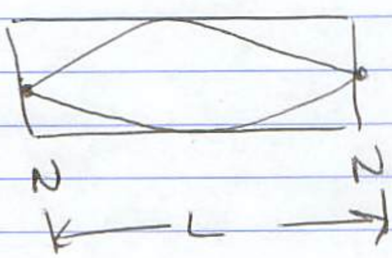
(b)

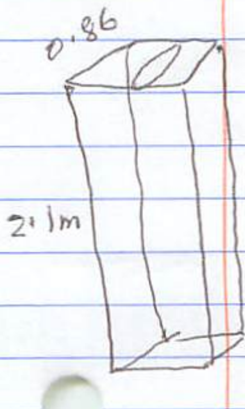



$$f = \frac{v}{2L} \Rightarrow L = \frac{1}{2}\left(\frac{v}{f}\right)$$

$$L = \frac{1}{2}\left(\frac{340\,\text{m/s}}{4000\,\text{Hz}}\right) = \boxed{0.0425\,\text{m}}$$

14-46




For a closed box, the resonant frequencies will have nodes at both sides.

$$L = n\frac{\lambda_n}{2} \text{ and } \lambda_n = \frac{v}{f_n}$$

$$\Rightarrow L = n\frac{1}{2}\frac{v}{f_n} = \frac{nv}{2f_n} \quad (n = 1, 2, 3, \ldots)$$

$$\Rightarrow \boxed{f_n = \frac{nv}{2L}}$$ with $L = 0.86$ m and $L' = 2.1$ m

11

If $L = 0.86m$

$$f_n = \frac{n(355 m/s)}{2(0.86)} = n\, 206 Hz$$

$$f_{n max} = 2000 Hz = n(206 Hz)$$

$$\Rightarrow n = \frac{2000}{206} = 9.7$$

closest integer for $\boxed{n = 9}$

$\Rightarrow f_n = n(206 Hz)$ for each n from 1 to 9.

If $L' = 2.1m$

$$f_n = \frac{n(355 m/s)}{2(2.1m)} = n(84.5 Hz)$$

$130 Hz < f_n < 2,000 Hz$

$$n(84.5) > 130 Hz \Rightarrow n > \frac{130}{84.5} \Rightarrow n > 1.5$$

$\therefore$ closest integer for $n = 2$

$$n(84.5) < 2000 Hz \Rightarrow n < \frac{2000}{84.5} \Rightarrow n < 23.7$$

$\therefore$ closest integer for $n = 23$

$\therefore f_n = n(84.5 Hz)$ for each n from 2 to 23

(12)

14-49

$$v = \sqrt{\frac{F}{\mu}} \Rightarrow v_1 = \sqrt{\frac{200N}{\mu}}$$

$$v_2 = \sqrt{\frac{196N}{\mu}}$$

$$f_1 = \frac{v_1}{\lambda_1} \quad \text{and} \quad f_2 = \frac{v_2}{\lambda_1}$$

$$f_{beat} = |f_1 - f_2|$$

$$\Rightarrow f_1 = \frac{v_1}{\lambda_1} \Rightarrow \frac{f_2}{f_1} = \frac{v_2/\cancel{\lambda_1}}{v_1/\cancel{\lambda_1}} = \frac{v_2}{v_1}$$

$$\text{and } \frac{v_2}{v_1} = \sqrt{\frac{196}{\cancel{\mu}} \cdot \frac{\cancel{\mu}}{200}} = \sqrt{\frac{196}{200}} = \sqrt{0.98}$$

$$\Rightarrow \frac{f_2}{f_1} = \frac{v_2}{v_1} = \sqrt{0.98} \Rightarrow \boxed{f_2 = f_1\sqrt{0.98}}$$

$$\Rightarrow f_2 = (523)\sqrt{0.98} = \boxed{517.74 \text{ Hz}}$$

$$\therefore f_{beat} = 523 - 517.74 = \boxed{5.26 \text{ Hz}}$$